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IMPROVED POINT-SOURCE AND LINE-SOURCE
COMPACT ANTENNA RANGES

R. C. Johnson

A. L. Holliman

Engineering Experiment Station
Georgia Institute of Technology

TECHNICAL REPORT NO. RADC-TR-67-473

October 1967

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**IMPROVED POINT-SOURCE AND LINE-SOURCE
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FOREWORD

This document constitutes the second interim report of research performed by the Engineering Experiment Station of the Georgia Institute of Technology, Atlanta, Georgia, under Contract AF30(602)-4269 with the Rome Air Development Center, Research and Technology Division, Air Force Systems Command, Griffiss Air Force Base, New York. The contract was initiated under Project 4506, Task 450604, and the technical direction at RADC was obtained from Mr. Martin Jaeger (EMATA). Dr. R. C. Johnson, and Dr. A. L. Holliman of the Georgia Tech Engineering Experiment Station prepared this report which describes research performed during the period 28 April 1966 to 28 June 1967.

The results of this program were possible because of the combined efforts of several persons at Georgia Tech and at RADC. Special thanks go to Mr. Jaeger of RADC, the program monitor, for his interest and suggestions.

The distribution of this report is limited because the information provided on a unique antenna measurement technique does not warrant its release to the general public.

This technical report has been reviewed and is approved.

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ABSTRACT

A point-source and a line-source "compact antenna range" were modified by installing on each range a reflector having a more accurate surface contour and by shielding the point-source reflector edge and its feed with absorbing material. Stray radiation measurements and antenna pattern measurements were made on both ranges at X-band (8.2 to 12.0 GHz) frequencies using a 30-inch paraboloidal test antenna; these measurements also were made on the point-source range at C-band (5.4 to 5.8 GHz) and at S-band (2.8 to 3.2 GHz) frequencies using pyramidal horn antennas. Results at X-band are compared with those obtained on previously constructed compact ranges, and they demonstrate that the range performance was improved. Antenna radiation patterns compare very favorably with those measured on outdoor antenna ranges.

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SECTION I

INTRODUCTION

Techniques which enable measurements with radar and other full-size microwave antennas to be made on indoor "compact antenna ranges" have been demonstrated previously.¹ A range reflector and special feed system close to the test antenna are used to produce incident plane waves, and far-zone results are obtained.

Two range configurations have been studied; they are a point-source range and a line-source range. The point-source range consists of a paraboloidal reflector with a horn feed, and the line-source range consists of a parabolic-cylinder reflector with a hoghorn feed.

The performance of any antenna range, conventional or compact, is limited by the presence of "stray" radiation which perturbs the desired incident plane wave. On conventional ranges, the primary causes of stray radiation are reflections from the ground and surrounding objects. On compact ranges, the sources of stray radiation include reflection and diffraction from the feed and its support, back radiation from the feed, edge effects of the range reflector, and phase effects due to the contour errors of the reflector. Stray radiation measurements have been discussed previously.^{1,2}

The work described in this report was conducted to improve the antenna measurement accuracies of compact antenna ranges and to extend the operating frequencies to the C- and S-band regions. Both ranges were modified by installing more accurate range reflectors, and C- and S-band feeds were

designed and fabricated for the point-source range. Some of the operating characteristics of the improved ranges are described, and comparisons are made with the corresponding results obtained previously.

SECTION II

THE POINT-SOURCE RANGE*

1. Range Description

The modified point-source compact antenna range (PSR-2) is shown in Figures 1 and 2. (For clarity, the previous point-source range and the modified point-source range hereafter will be referred to as PSR-1 and PSR-2, respectively.) It consists of a 10-foot spincast paraboloidal range reflector which is illuminated by a special waveguide feed horn (oriented for vertical polarization during the current study). A 30-inch paraboloidal dish, mounted on an azimuth-over-elevation positioner, is shown as the test antenna. The positioner is mounted on a movable table which travels on two sets of orthogonally oriented tracks allowing movement of the test antenna to any position inside a 4-foot square floor area.

For operation at X-band frequencies, the feed horn is an open-ended waveguide surrounded by a pyramidal horn in which the internal walls are lined with absorbing material. This absorbing material reduces back radiation from the horn and causes the radiation to drop off sharply for low illumination at the edges of the reflector. Additional absorbing material is located behind and below the feed-horn assembly to further reduce back radiation and diffraction from the feed and its supports.

For operation at C-band and at S-band frequencies, special diagonal feed horns⁴ were used to provide low back radiation and low reflector-edge illumination.

*Part of this discussion was presented in a previous interim report,³ and it is included here for completeness.

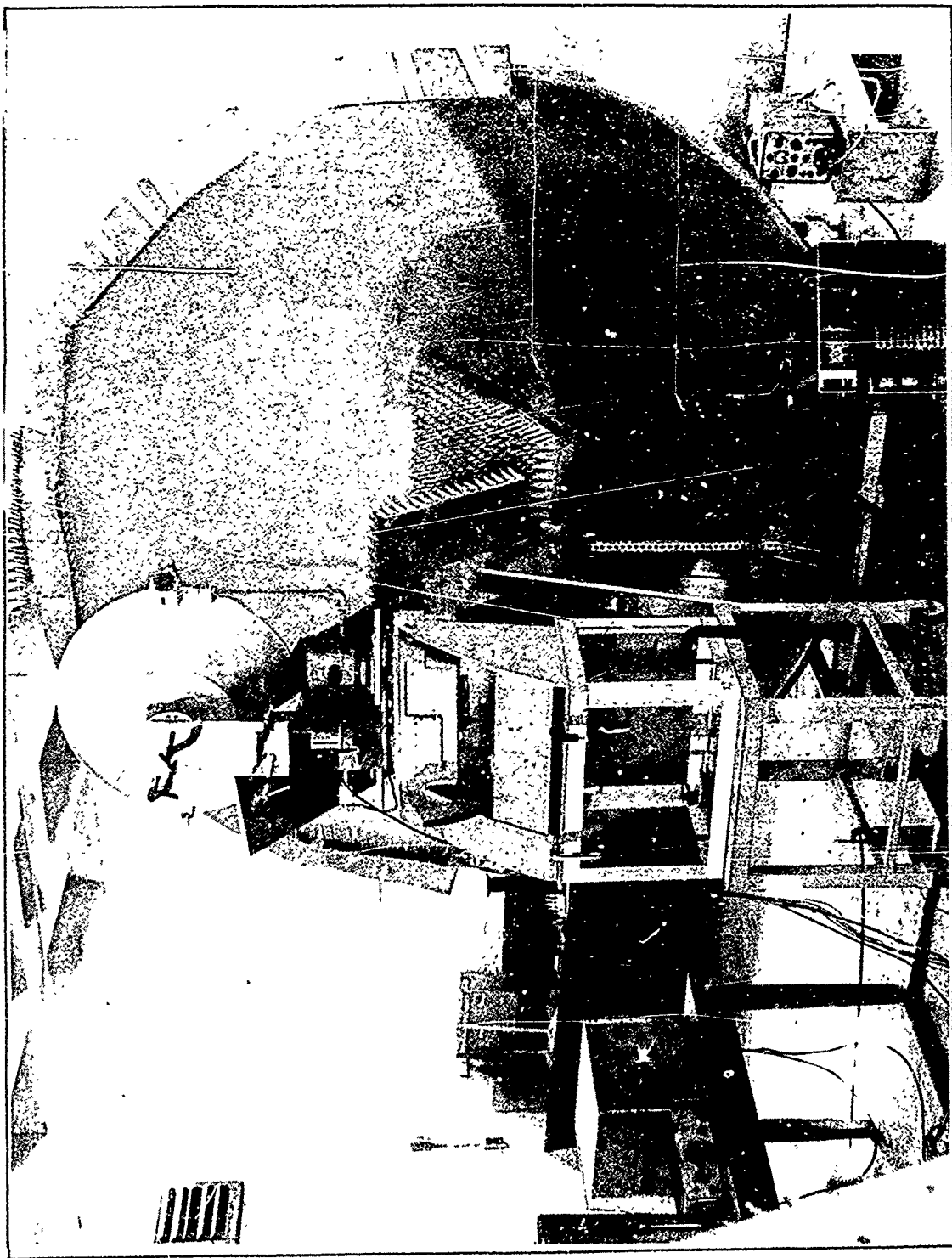


Figure 1. Modified point-source compact antenna range (FSR-2).

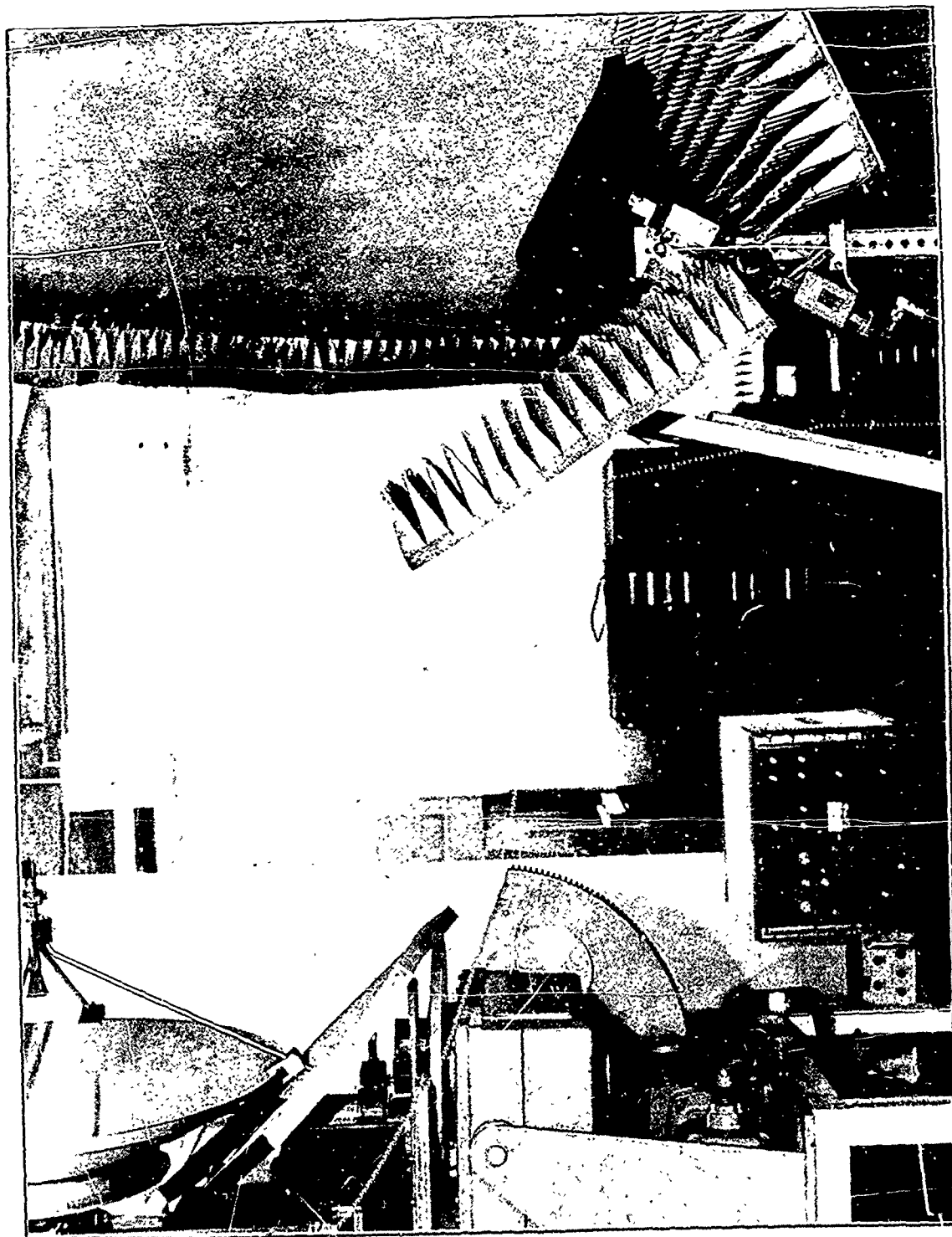


Figure 2. Feed horn, absorber-material shielding, and test antenna on the modified point-source range.

In order to reduce reflection and diffraction from the feed and its supports, the feed is oriented such that the peak of the feed-horn radiation pattern is aimed at the center of the top half of the reflector as shown in Figure 3. The feed then gives approximately uniform illumination in the central portion of the upper half of the reflector. Thus, the main beam of collimated energy comes off the reflector above the feed horn, and only the upper portion of the range reflector is actually used, as can be seen in Figure 3.

The reflector on the modified range (PSR-2) is more accurate than that on the previous range (PSR-1). The characteristics of the range reflectors are the following:

	<u>PSR-1</u>	<u>PSR-2</u>
Diameter	10 feet	10 feet
Focal Length	35.8 inches	30 inches
Contour Tolerance	± 0.060 inch	± 0.002 inch.

It should be noted that the above tolerances are those specified by the manufacturers. Some efforts were made at Georgia Tech to verify the contour accuracy of the PSR-2 reflector, and the results indicate that the surface errors are considerably greater than ± 0.002 inch.

It will be shown later that the stray radiation on the range was considerably reduced after the installation of the more accurate reflector. This indicates that errors in the reflector surface are a significant source of stray radiation.

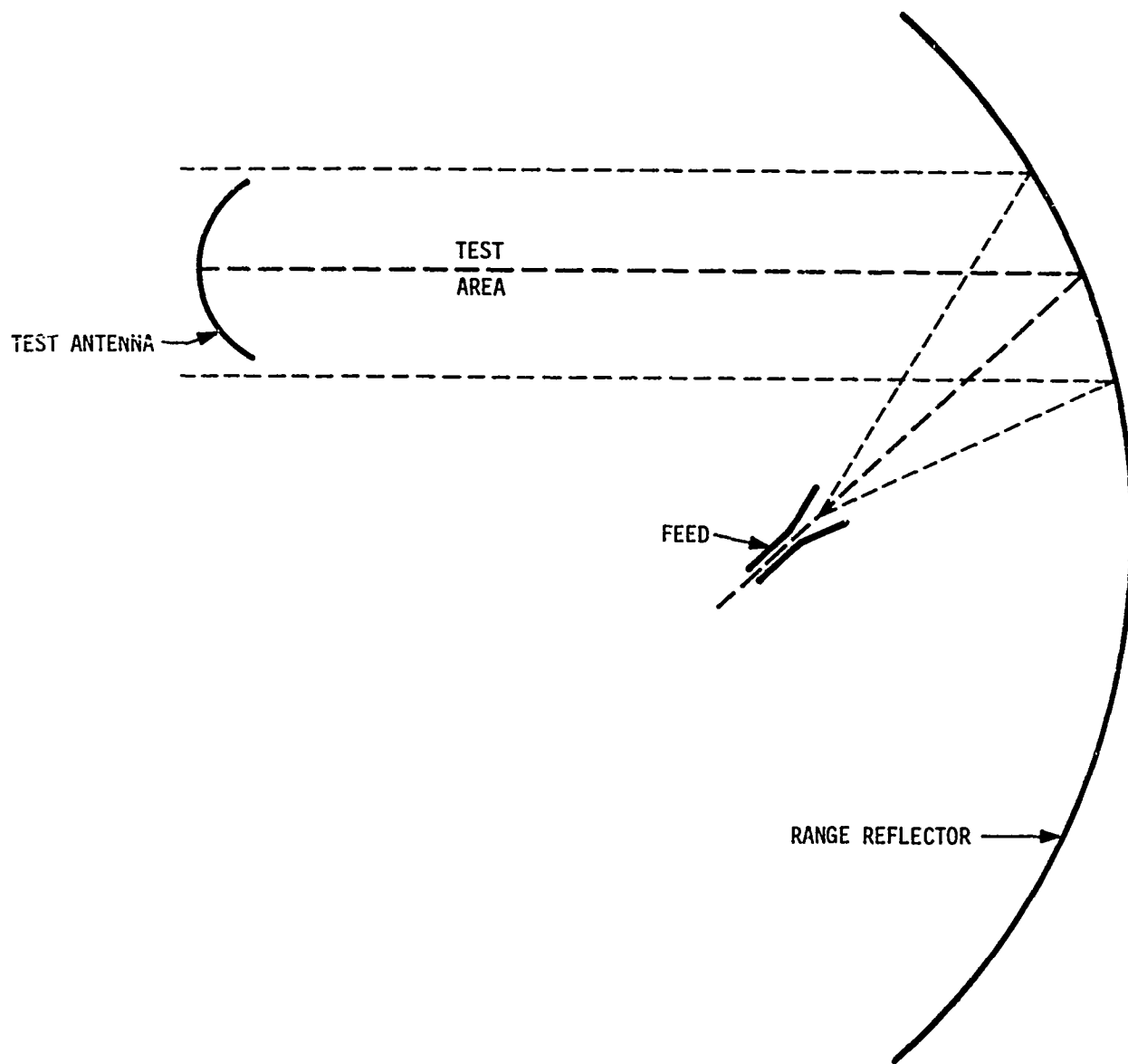


Figure 3. Schematic drawing of the point-source compact antenna range showing the available test region.

The discontinuity at the edge of the range reflector interrupts the normal flow of currents, producing stray radiation not in phase with the collimated radiation. This stray radiation was significantly reduced by the location of absorbing material around the periphery of the upper half of the reflector as shown in Figure 1.

2. Test Antennas

For operation at X-band frequencies, a 30-inch paraboloidal dish was used as a test antenna as shown in Figure 1. For operation at C-band and at S-band frequencies, pyramidal horns having E x H plane aperture dimensions of $6\text{-}5/16 \times 8\text{-}1/2$ inches and $9\text{-}7/16 \times 12\text{-}3/4$ inches, respectively, were used as test antennas.

3. Range Evaluation

a. Pattern Comparisons

A set of patterns of the 30-inch test antenna was recorded at X-band frequencies on the modified point-source range and was compared with a similar set of patterns previously recorded on the 700-foot outdoor range. The data include 360-degree and 60-degree expanded azimuth-plane patterns and 60-degree expanded elevation-plane patterns through the beam maximum. All of the above patterns were recorded at frequencies of 8.2, 9.0, 10.0, 11.0, and 12.0 GHz.

A similar set of azimuth and elevation patterns of the previously described pyramidal horn test antennas was recorded at C-band and at S-band frequencies on the modified point-source range and then compared with patterns recorded on a long outdoor range. These patterns were recorded at C-band frequencies of 5.4, 5.5, 5.6, 5.7, and 5.8 GHz and at S-band frequencies of 2.8, 2.9, 3.0, 3.1, and 3.2 GHz.

The pattern comparisons were very good; typical azimuth comparisons are illustrated in Figures 4, 5, and 6. Additional azimuth and elevation comparison patterns are presented in the Appendix.

As mentioned previously, the antenna positioner is mounted on a movable table; this allows one to record patterns with the test antenna located at many different positions within the test region. Figures 7, 8, and 9 show families of ten such patterns for three different frequencies. The patterns at a given frequency are not identical since the relative phase of the stray radiation is different for each pattern; however, note that the patterns compare closely.

b. Stray Radiation

As mentioned earlier, a factor which limits the performance of any antenna range is the interference of stray radiation with the collimated radiation. Major efforts to improve the performance of compact ranges have been directed, therefore, toward reducing the level of stray radiation.

The procedure for measuring the stray radiation was the same as that previously employed,¹ and it is similar to one outlined by Buckley.² The test antenna was positioned to receive power on a particular side lobe, and then was moved along the direction of propagation of the collimated energy. This changed the relative phase between the collimated radiation and the stray radiation, thus causing variations in the apparent level of a specific side lobe. To a first approximation, the change in the level of a specific side lobe is caused by the stray radiation received by the main lobe of the test antenna. The peak-to-peak variation (with movement of the test antenna) of a particular side lobe can be used to calculate the magnitude of

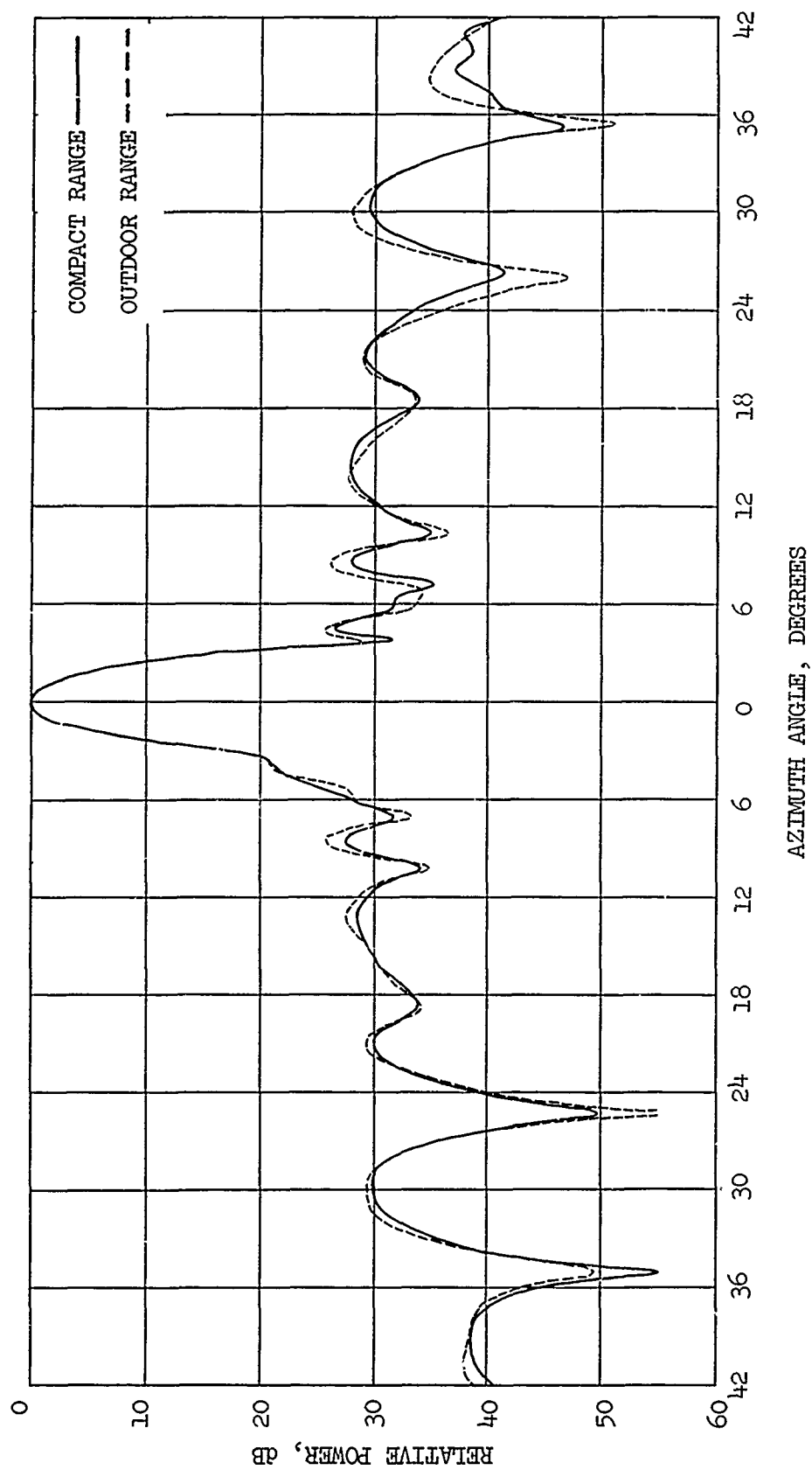


Figure 4. Comparison of the azimuth patterns on the outdoor range and on the modified point-source range at 10 GHz.

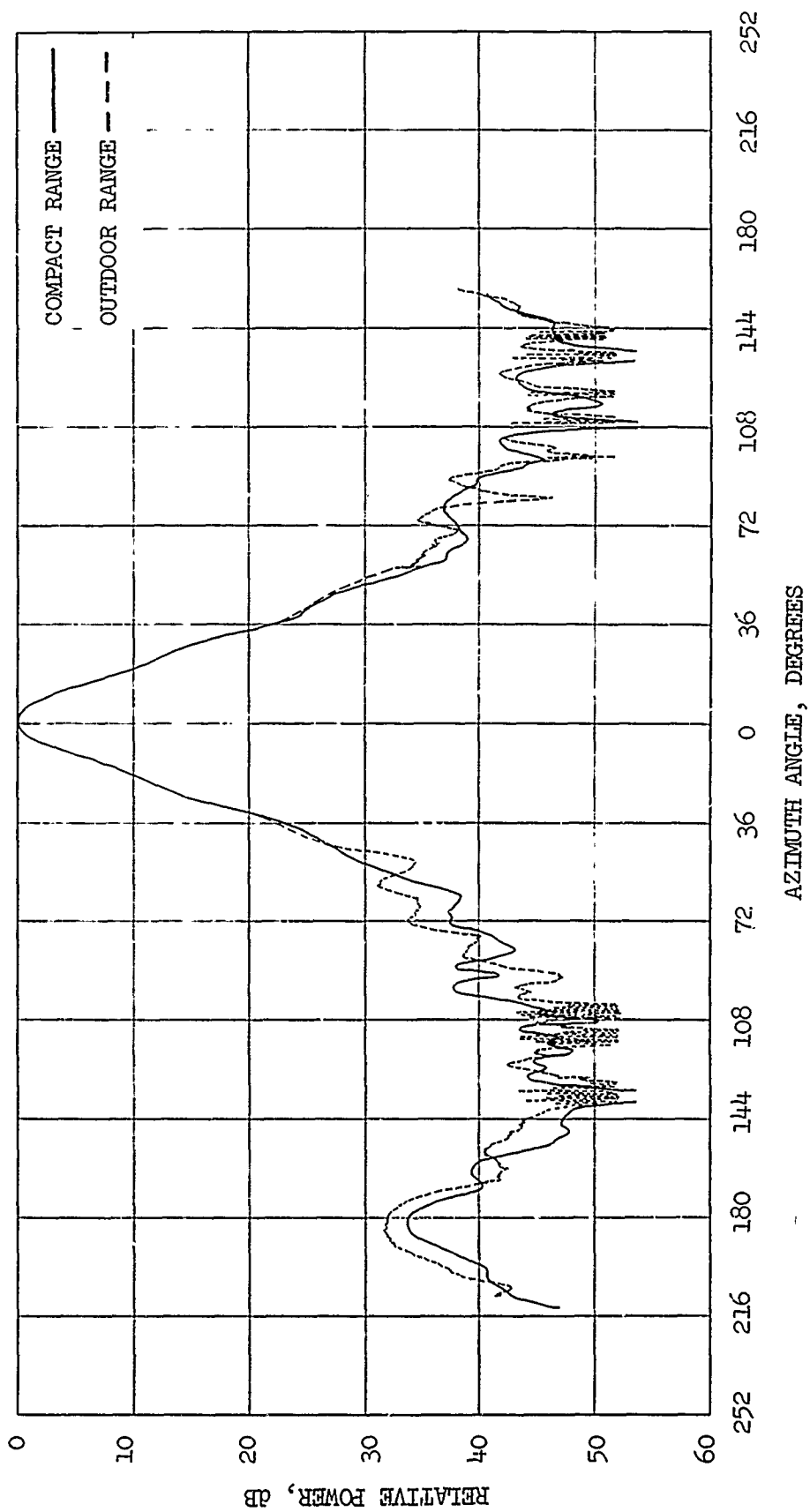


Figure 5. Comparison of the azimuth patterns on the outdoor range and on the modified point-source range at 5.6 GHz.

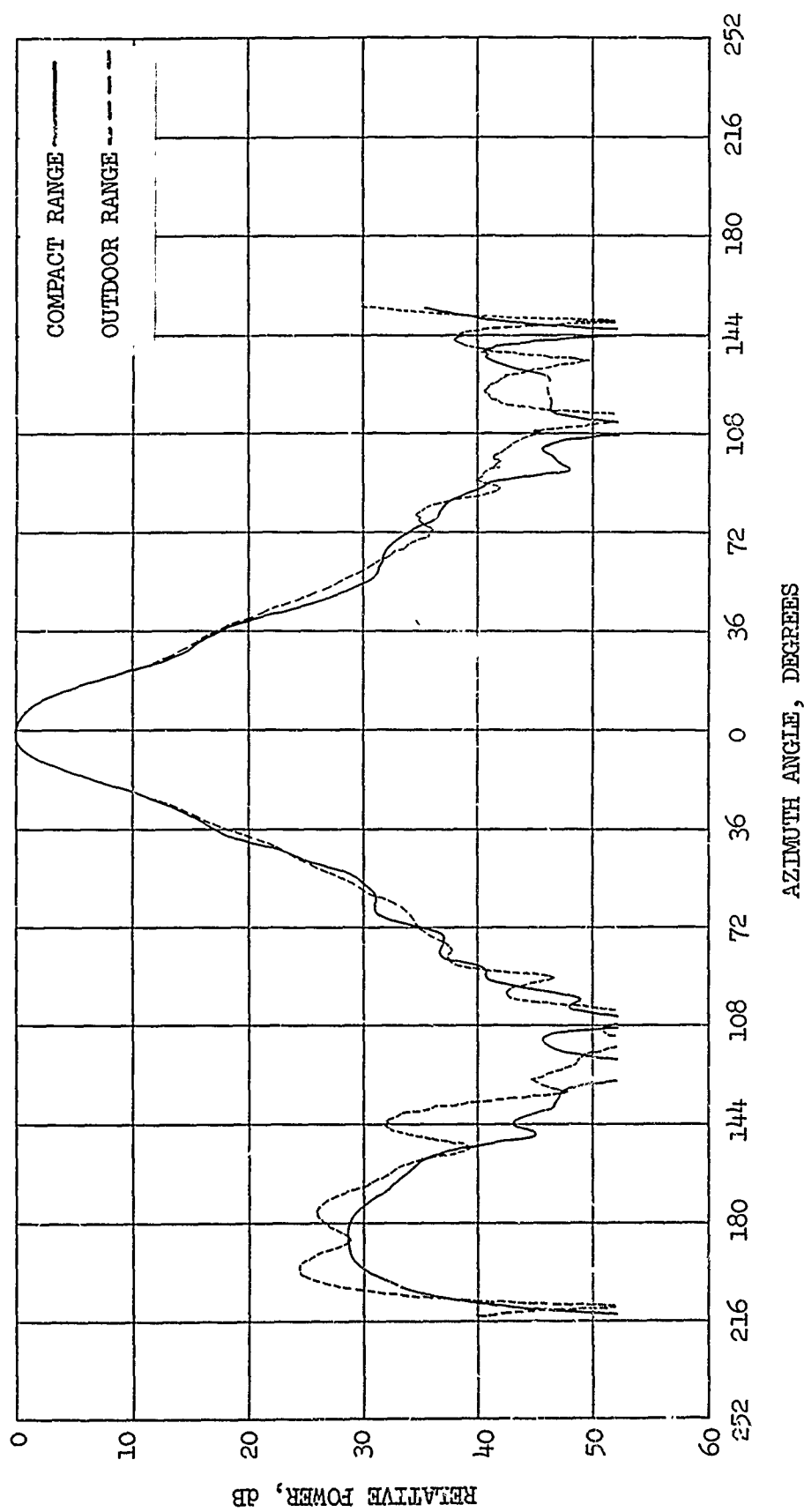


Figure 6. Comparison of the azimuth patterns on the outdoor range and on the modified point-source range at 3.0 GHz.

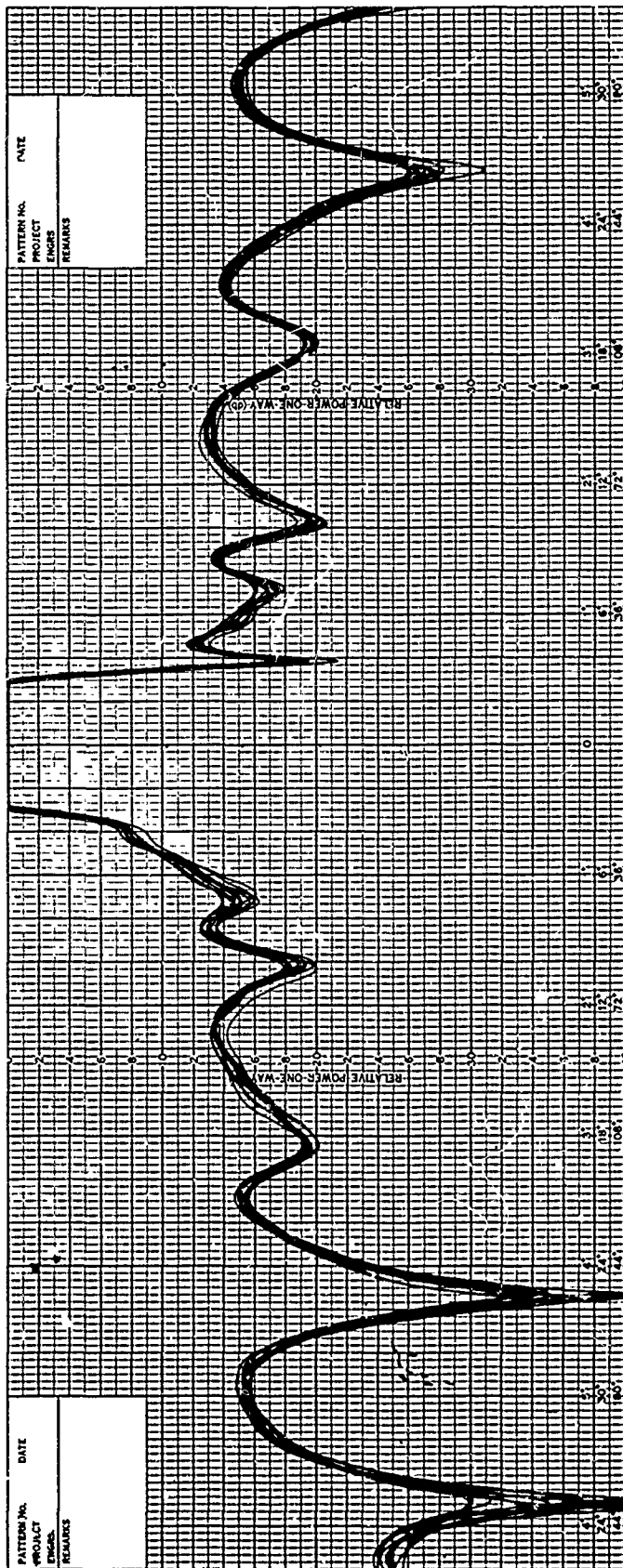


Figure 7. Composite set of azimuth patterns recorded on the modified point-source range (PSR-2) at 10 GHz. Each of the ten patterns was recorded with the test antenna located at a different location within the test area. The gain level at the top of the chart is -13 dB relative to the peak of the main lobe.

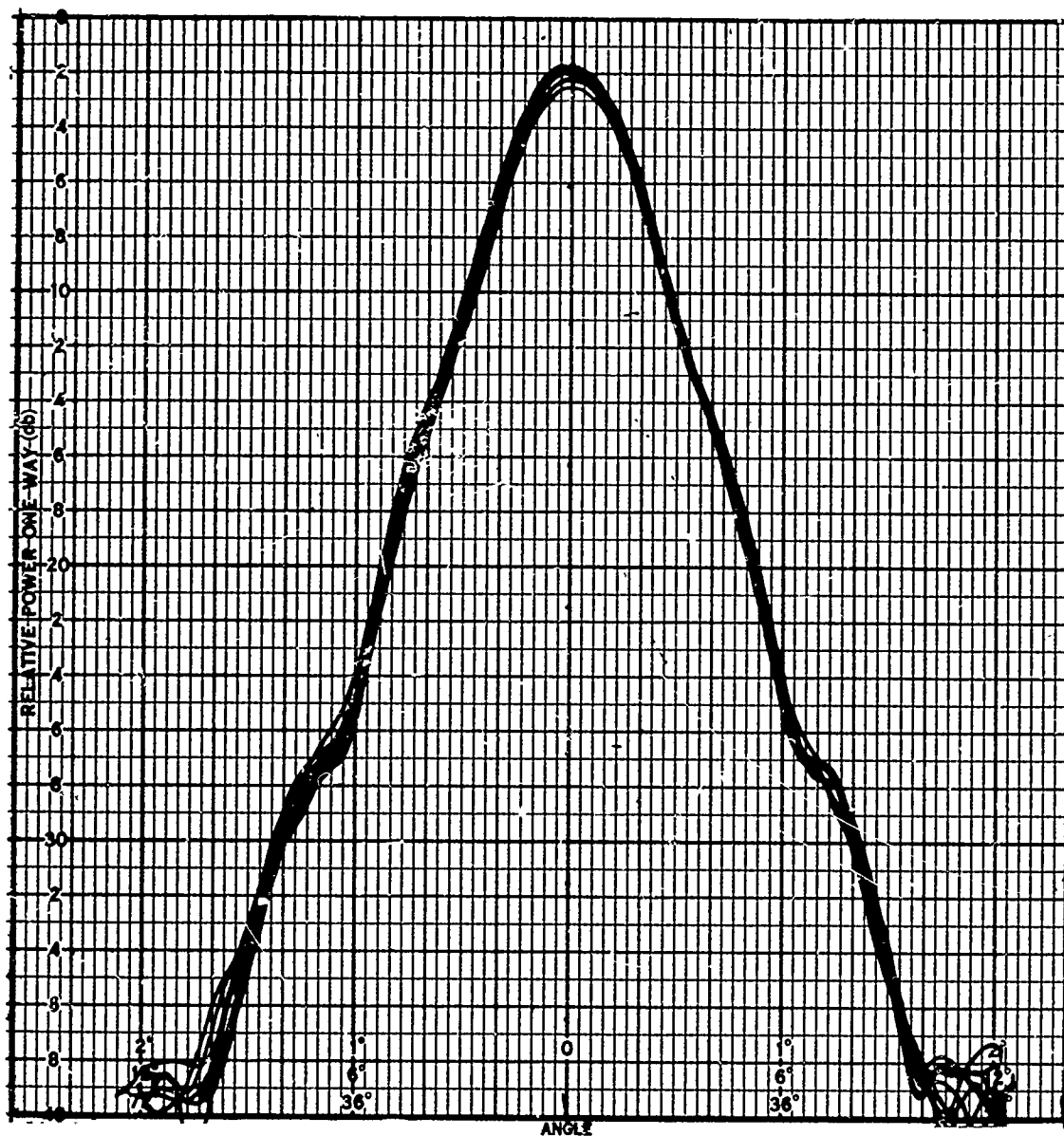


Figure 8. Composite set of azimuth patterns recorded on the modified compact range (PSR-2) at 5.6 GHz. Each of the ten patterns was recorded with the test antenna located at a different position within the test area.

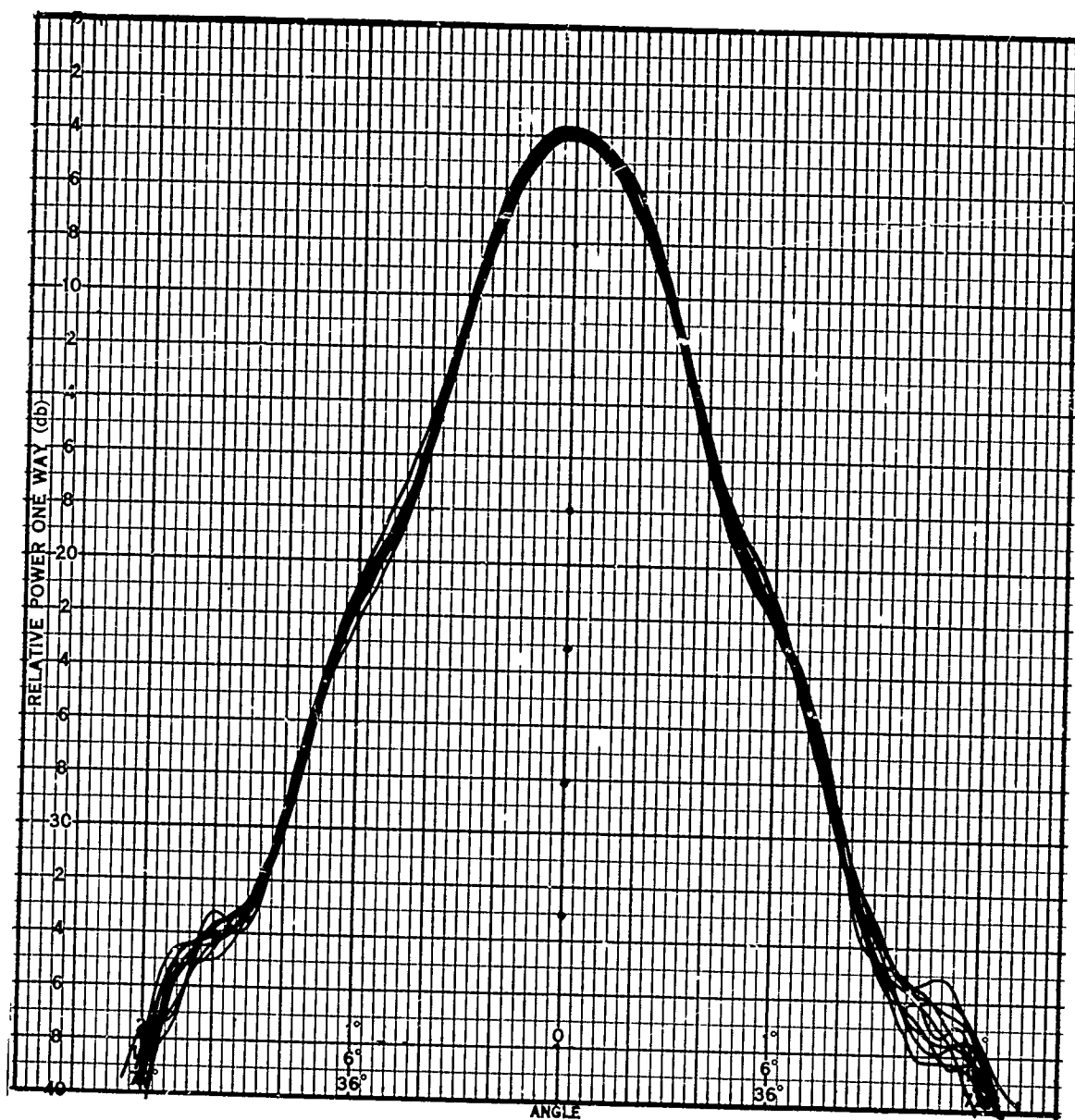


Figure 9. Composite set of azimuth patterns recorded on the modified compact range (PSR-2) at 3.0 GHz. Each of the ten patterns was recorded with the test antenna located at a different position within the test area.

stray radiation coming from the direction in which the main lobe is pointing. Thus, by following the above procedure for each side lobe, the stray radiation can be measured as a function of the azimuth angle of the test antenna.

There is a significant difference between the procedure outlined by Buckley and the procedure employed here. Buckley averages the peak-to-peak side lobe variations and uses this average value to calculate the stray radiation; whereas, the method employed here uses the maximum value of the side lobe variations to calculate the level of stray radiation. Note that the Buckley method measures the average stray radiation level, whereas the method employed here measures the maximum stray radiation level.

The measured maximum value of stray radiation on the modified range versus azimuth angle for each test frequency at X-, C-, and S-band is shown in Figures 10, 11, and 12, respectively. The stray radiation measured on the previous range at X-band is shown in Figure 13. Note that stray radiation at X-band on the modified range was reduced about 10 dB below that on the previous range but that stray radiation at C- and S-band was higher than at X-band. The stray radiation at the lower frequencies appears higher because the broad main lobes of the test antennas illuminate many sources of stray radiation, such as back radiation and scattering from the range feed, which are not illuminated by the narrow beam of the X-band test antenna.

c. Coupling Between Range and Test Antenna

The effect of coupling between the range and the test antenna can be illustrated by measuring the variation of received power as the distance between the test antenna and the range reflector is varied; results are shown in Figure 14. For these measurements, a synchro transmitting unit was rigged to track the rails on which the antenna positioner traveled. The synchro provided position data to the pattern recorder; this allowed the recorder chart to track

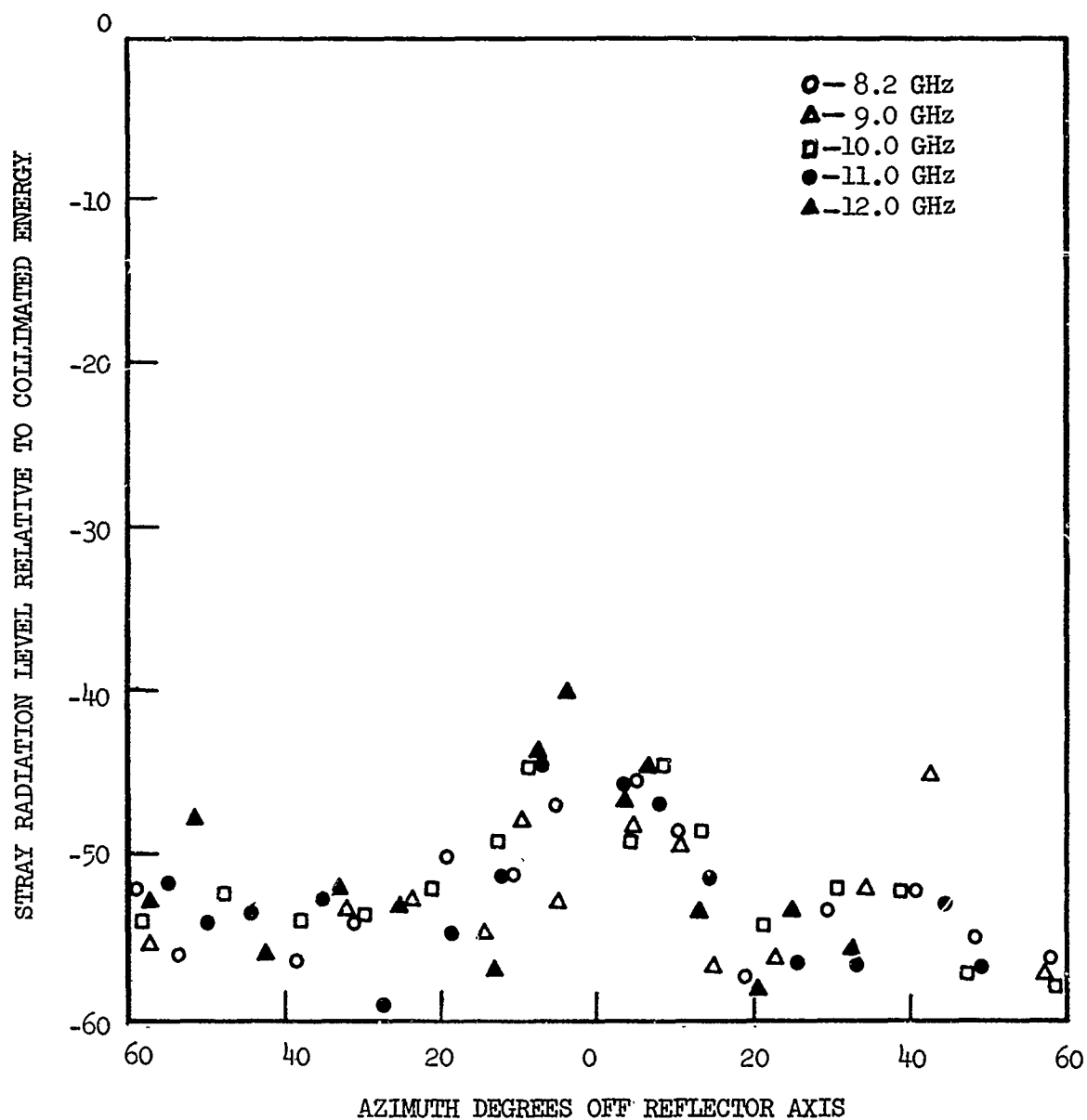


Figure 10. Maximum stray radiation levels as a function of azimuth angle of the test antenna as measured on the modified point-source range (PSR-2) at X-band frequencies.

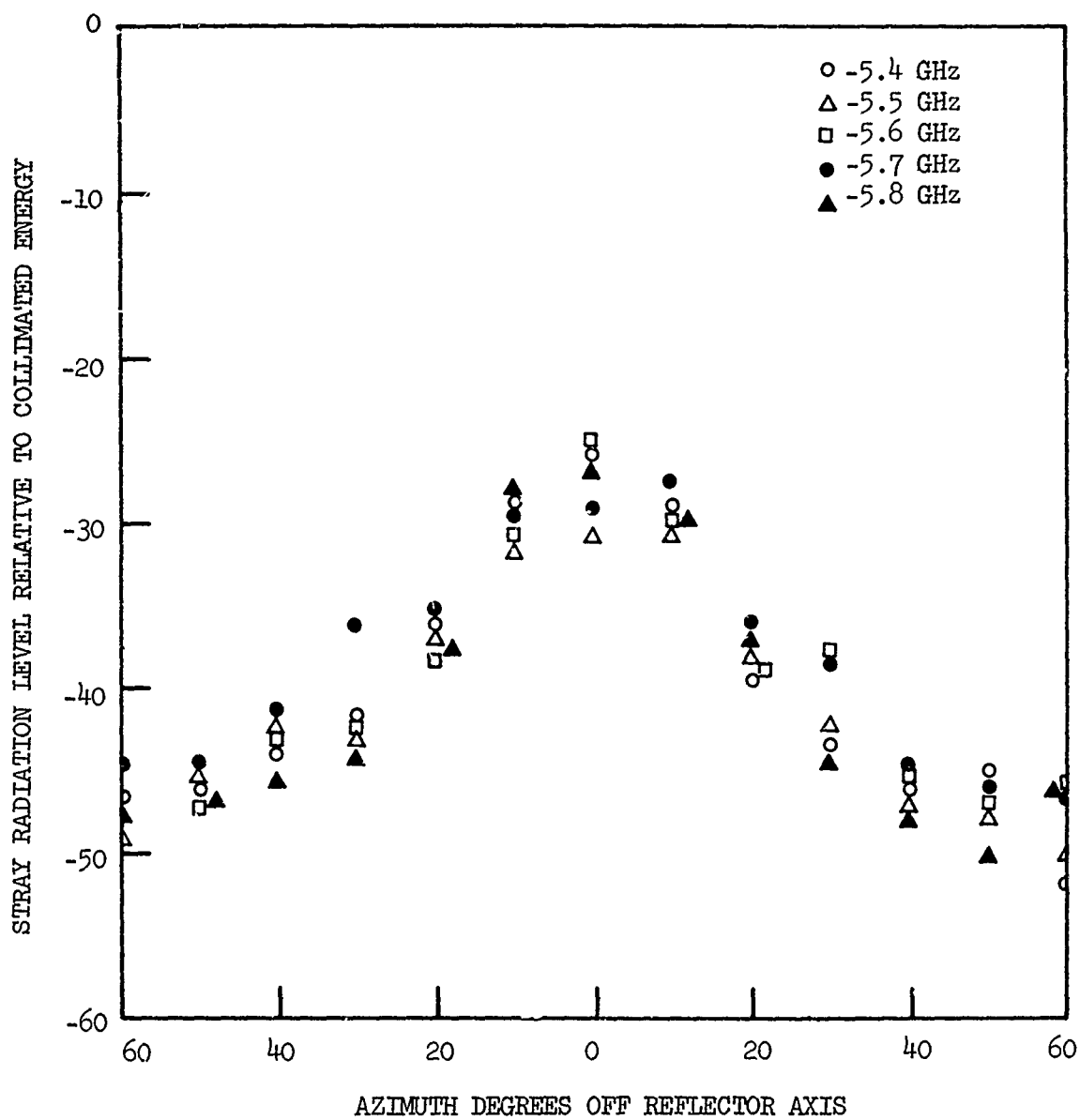


Figure 11. Maximum stray radiation levels as a function of azimuth angle of the test antenna as measured on the modified point-source range (PSR-2) at C-band frequencies.

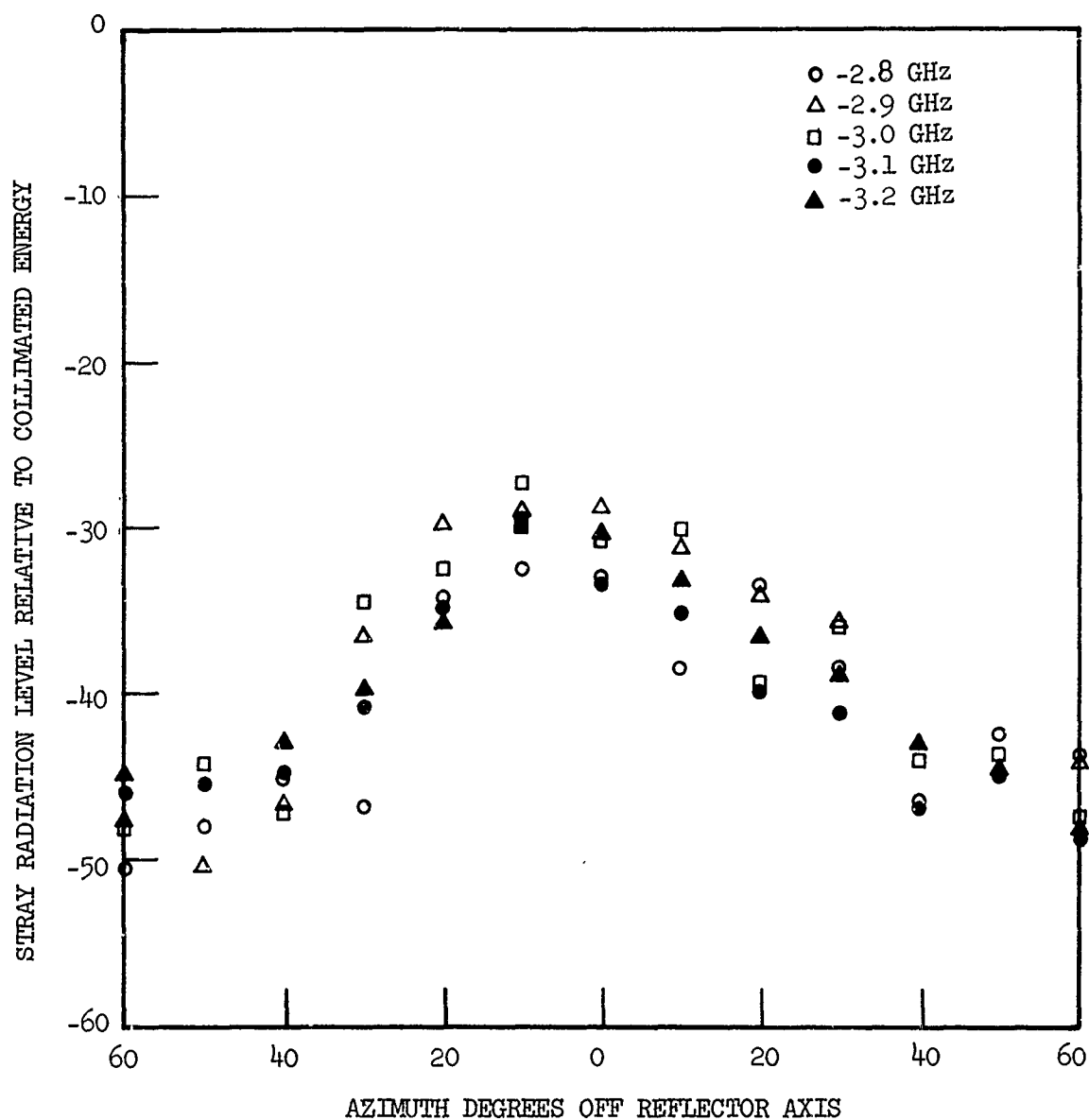


Figure 12. Maximum stray radiation levels as a function of azimuth angle of the test antenna as measured on the modified point-source range (PSR-2) at S-band frequencies.

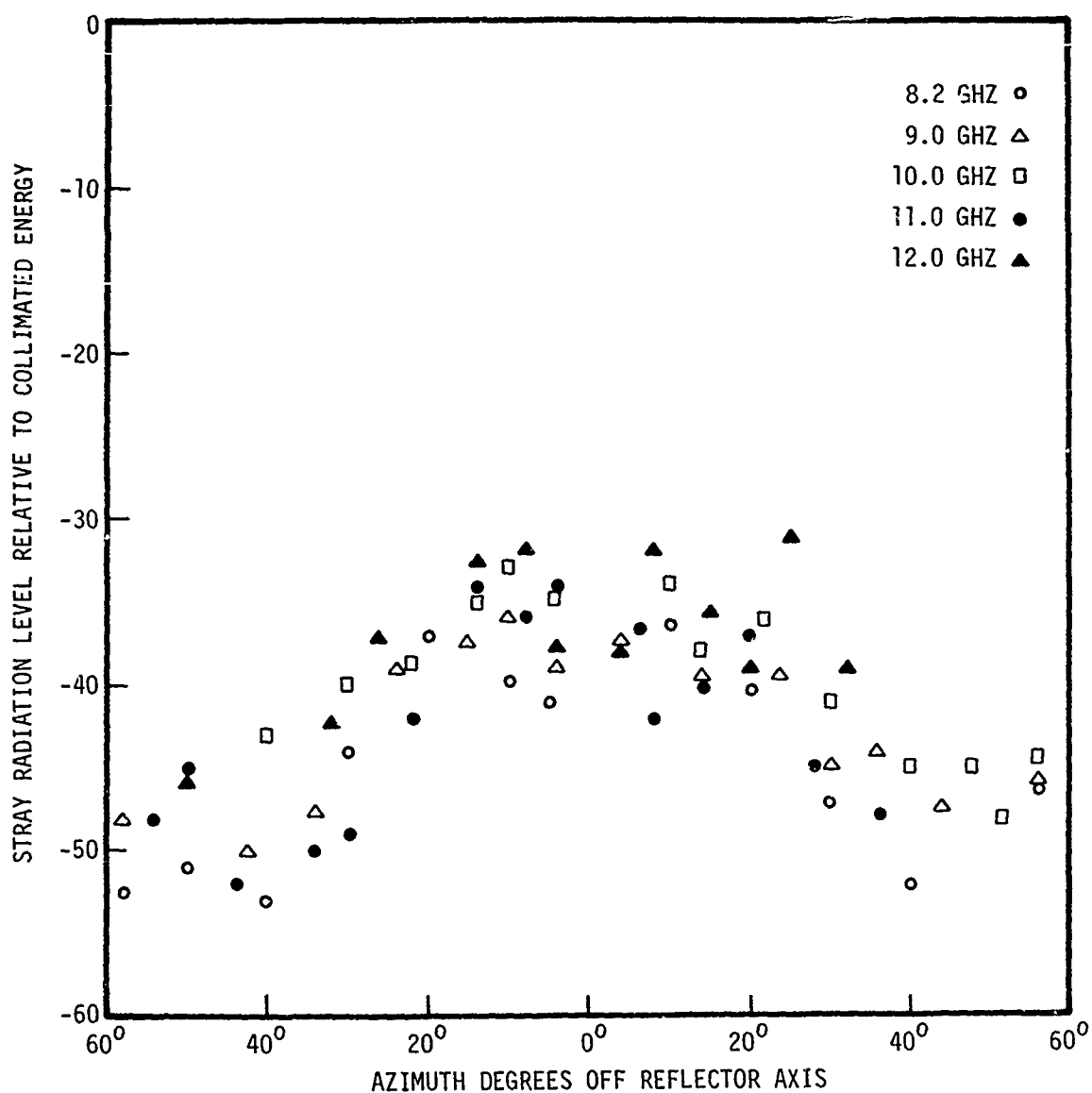


Figure 13. Maximum stray radiation levels as a function of azimuth angle of the test antenna as measured on the previous point-source range (PSR-1) at X-band frequencies.

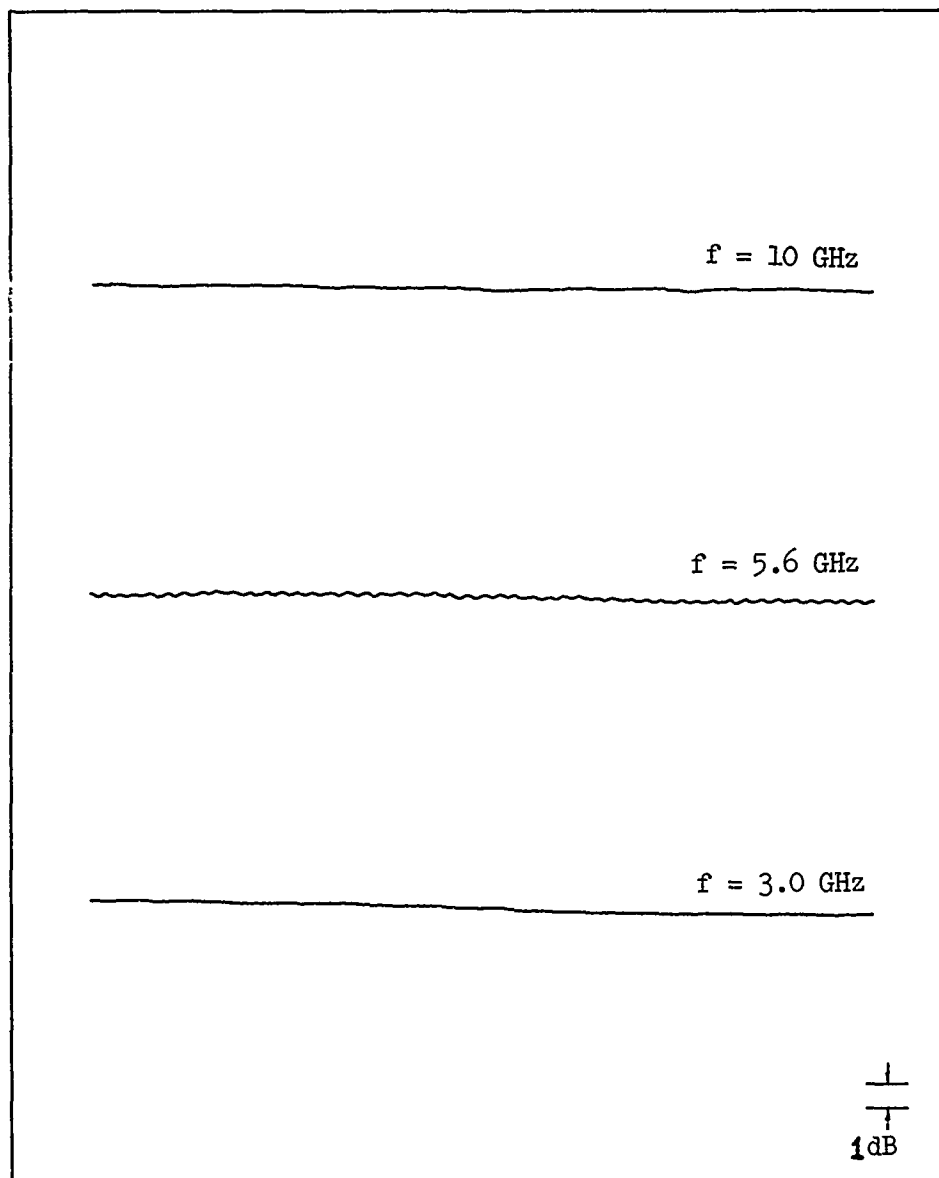


Figure 14. Power received as a function of the separation between the test antenna and the point-source range reflector. At each of the indicated frequencies, the test antenna was moved a distance of about four feet.

the position of the test antenna. The measurements demonstrate that the mutual coupling between the compact range and the main lobe of the test antenna was small.

Some coupling was observed when the test antenna was oriented to receive the collimated power on a side lobe; this coupling causes errors like those caused by stray radiation. Efforts were not made to separate the effects of coupling from those of stray radiation since the observed effects were small; therefore, the measured stray radiation levels presented in this report include any effects of minor-lobe coupling.

d. Gain Comparisons

The gain of the 30-inch test antenna was measured at five X-band frequencies on the outdoor and on the compact antenna range using a standard gain horn as a reference antenna. The measurements agreed within 0.2 dB, as was the case with the PSR-1 range.¹ The test antennas for the C- and S-band measurements were standard gain horns. The small mutual coupling observed with these antennas indicate that reliable gain measurements can be made also at C- and S-band.

e. Polarization Measurements

The on-axis cross-polarized component of field was measured at X-, C-, and S-band using pyramidal horn test antennas. After a reference level was determined for the parallel-polarized component, the horn was rotated ninety degrees to determine the relative level of the cross-polarized component. The cross component was found to be at least 40 dB below the parallel component, as was the case with the PSR-1 range.¹

4. Results

Measurements made on the point-source range demonstrate that far-zone results can be obtained with an indoor compact antenna range. The azimuth

patterns, recorded on the outdoor and on the compact range, compare well over a dynamic range exceeding 40 dB.

The measurements also indicate that the performance of the modified range was improved. Stray radiation at X-band was reduced approximately 10 dB on the modified point-source range as compared with the previous range; this reduction in stray radiation increases the accuracy of antenna pattern measurements.

It was demonstrated at X-, C-, and S-band that the main-lobe coupling between the test antenna and the compact range was small; this allows one to make accurate gain measurements. The gain measurements made on the compact range agree with those made on the outdoor range within 0.2 dB. Polarization measurements indicated that the on-axis cross component was more than 40 dB below the parallel component.

Measurements indicated higher stray radiation at C- and S-band than at X-band. The higher stray radiation at the lower frequencies was attributed to the broad main lobes of the test antennas which illuminate many sources of stray radiation. Supporting data were obtained on the line-source range where stray radiation measured with a small pyramidal horn appeared to be about 10 dB higher than that measured with the 30-inch paraboloidal test antenna (see Figures 17 and 25). The measured stray radiation depends upon the beamwidth of the test antenna; this is expected to be true of any antenna range, including conventional outdoor ranges. There is no inherent reason to expect higher stray radiation at lower frequencies if the test conditions are equivalent to those employed at X-band.

SECTION III

THE LINE-SOURCE RANGE

1. Range Description

The modified line-source compact antenna range (LSR-2) as shown in Figure 15 consists of a hoghorn feeding a section of a parabolic-cylinder reflector. (For clarity, the previous line-source range and the modified line-source range hereafter will be referred to as LSR-1 and LSR-2, respectively.) The specially constructed hoghorn forms a tapered-illumination line source which is approximately eight feet long. The parabolic barrier in the hoghorn is estimated to conform to a true parabolic contour within about ± 0.004 inch. This accuracy is desired to insure that the emerging wave will have a nearly constant phase front. The range reflector is a section of a parabolic cylinder approximately nine feet wide by six feet high which collimates the energy in the elevation plane, producing the desired plane wave from its aperture. The antenna positioner was mounted on the same track arrangement as was used on the point-source range; this allowed movement of the test antennas to any position within a 4-foot square floor area.

The new range reflector was constructed of relatively light-weight fused-silica-foam blocks cemented together. An accurate silica cement surface was then swept over this block structure by a rigid straight edge guided on accurately machined parabolic templates. This procedure produced a smooth parabolic-cylindrical surface within close tolerances. Measurements indicate that the surface of the parabolic cylinder conforms to a true parabolic cylinder within about ± 0.010 inch. A silver paint then was sprayed onto the



Figure 15. Modified line-source compact antenna range (ISR-2).

surface to provide a conductive coating. The resulting reflector possesses a very accurate surface that is rigid, relatively light-weight, and thermally stable.

2. Range Evaluation

a. Pattern Comparisons

A set of patterns similar to that recorded on the point-source range was recorded on the line-source range and was compared with patterns previously recorded on the outdoor 700-foot range. The pattern comparisons were very good. A typical comparison is illustrated in Figure 16, and additional azimuth and elevation comparison patterns are presented in Appendix A.

b. Stray Radiation

The procedure for measuring stray radiation on the line-source range was the same as that used on the point-source range. The test antenna was positioned to receive power on a particular side lobe, and then it was moved along the direction of propagation of the collimated energy to introduce phase changes between the stray and collimated energy. A plot of the measured maximum stray radiation as a function of azimuth angle on the modified line-source range is shown in Figure 17, and similar data measured on the previous line-source range is shown in Figure 18. Note that stray radiation measured on the modified range is less than that measured on the previous range.

c. Coupling Between Range and Test Antenna

The coupling between the main lobe of the test antenna and the line-source range was measured in a manner similar to that used on the point-source range; and negligible coupling was observed.

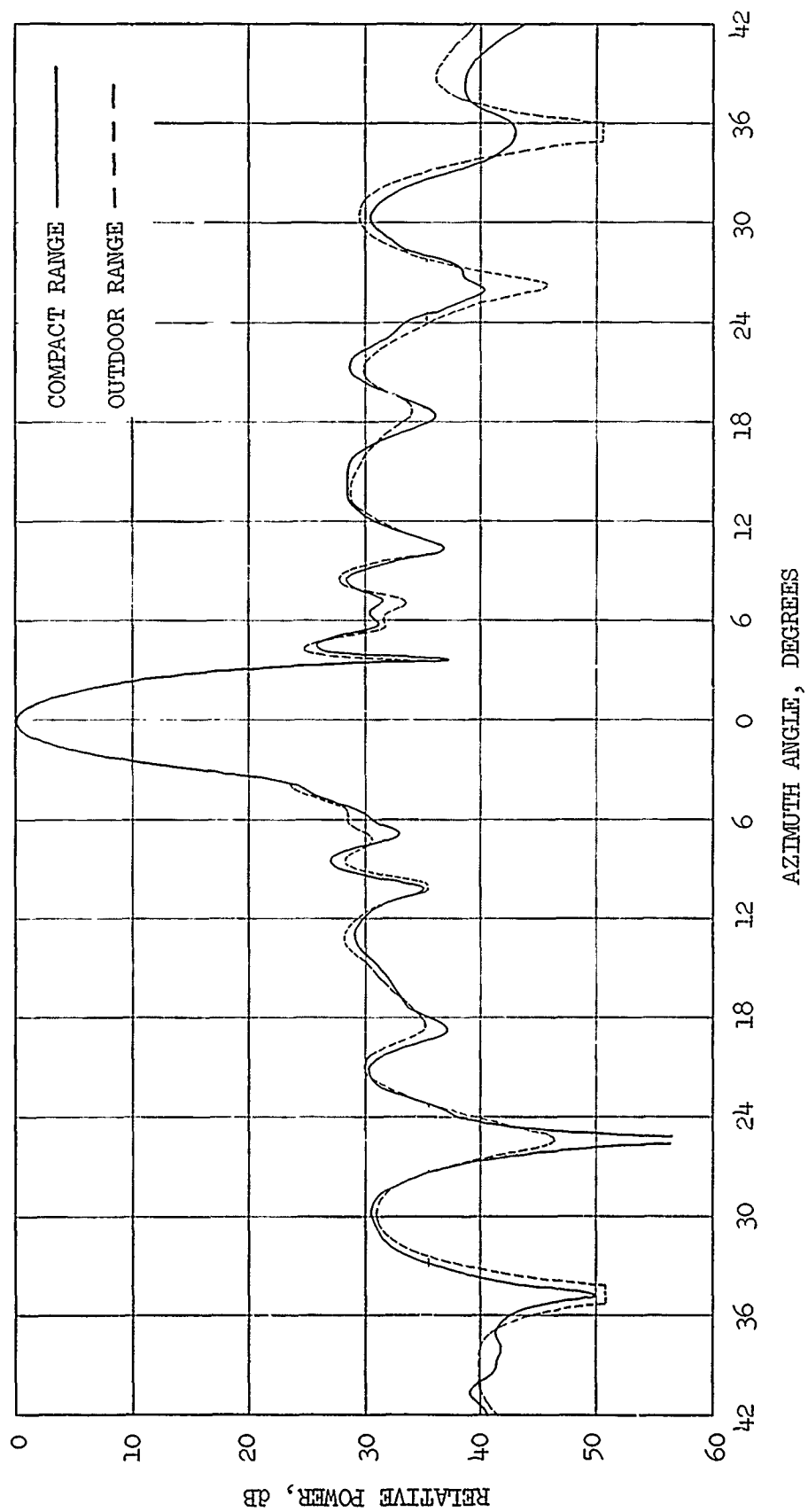


Figure 16. Comparison of the azimuth patterns on the outdoor range and on the modified line-source range at 10 GHz.

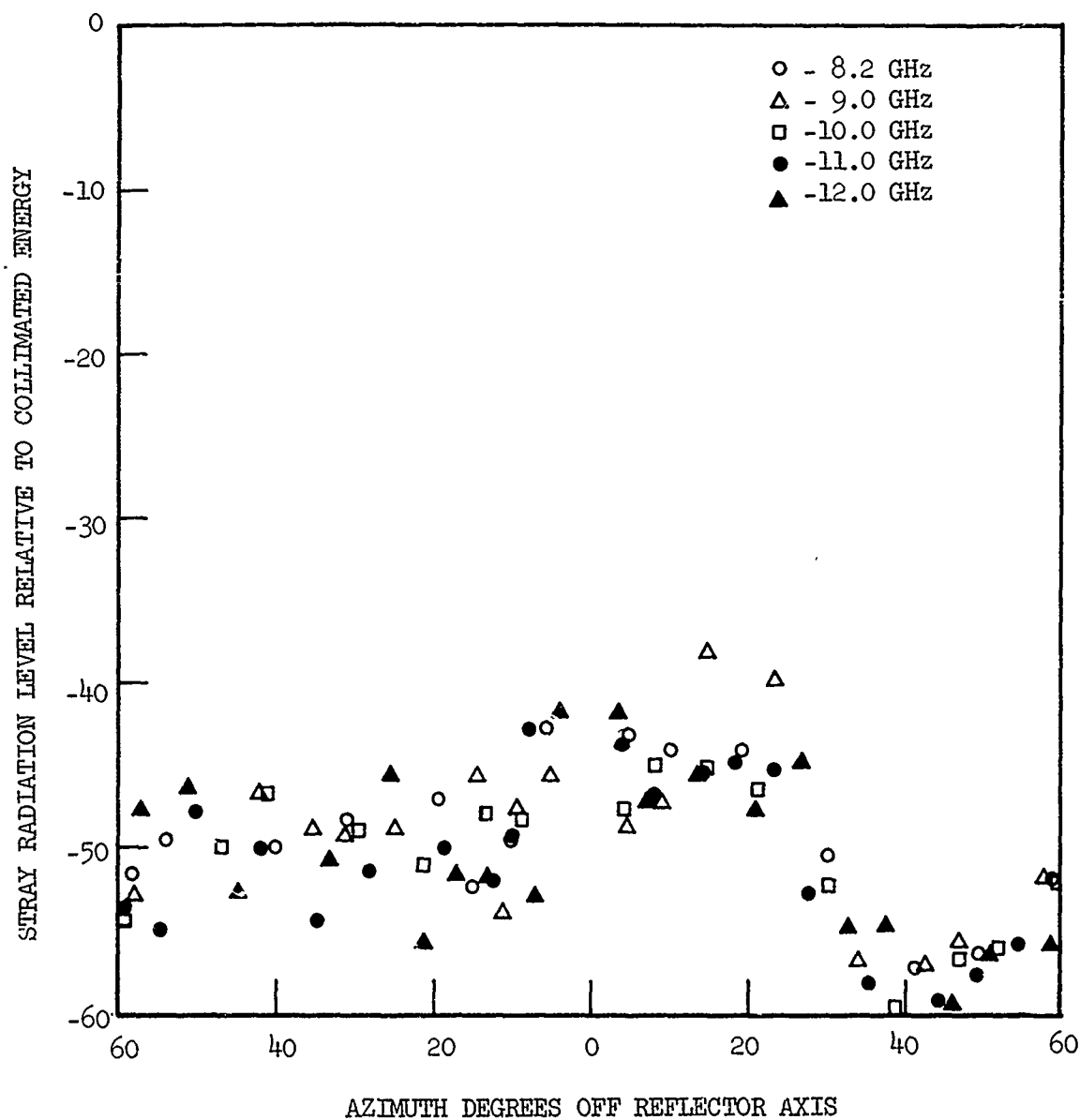


Figure 17. Maximum stray radiation levels as a function of azimuth angle of the test antenna as measured on the modified line-source range at X-band frequencies (with a 30-inch paraboloidal test antenna).

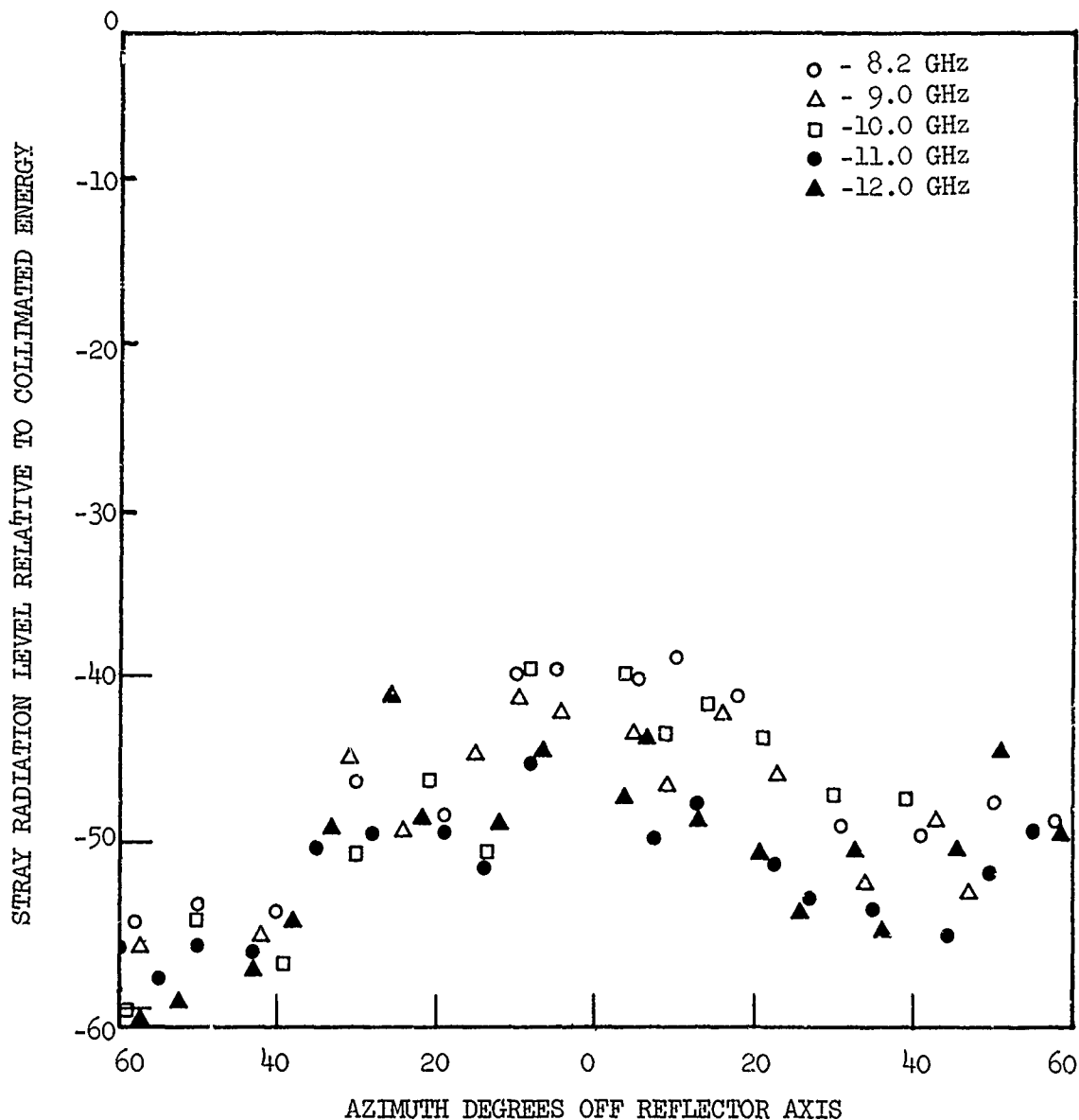


Figure 18. Maximum stray radiation levels as a function of azimuth angle of the test antenna as measured on the previous line-source range at X-band frequencies (with a 30-inch paraboloidal test antenna).

d. Gain Comparisons

The gain measurements on the previous line-source range indicated that the gain of the 30-inch test antenna ranged from about 0.5 dB to 1.0 dB below the values measured on both the outdoor range and on the point-source compact range. The gain measurements on the outdoor range and on the point-source range agreed within 0.2 dB. The fact that the gain measurements on the line-source range do not agree with the outdoor measurements is attributed to the tapered amplitude distribution in the vertical plane on the line-source range. Whereas the amplitude distribution across the 30-inch test region of the point-source range was tapered less than 1 dB, it was found to be tapered approximately 4 dB in the vertical plane of the line-source range.

Although the gain measurements made on the line-source range do not agree well with those made on the outdoor range, the source of error can be corrected by modifying the amplitude distribution in the elevation plane. Then results would be similar to those obtained on the point-source range.

e. Polarization Measurements

The on-axis cross-polarized component of field was measured in the same manner as that used on the point-source range, and it was observed to be at least 40 dB below the parallel component.

3. Results

The azimuth and elevation patterns recorded on the modified line-source range agree well with those recorded on the outdoor range over a dynamic range exceeding 40 dB. The measured maximum stray radiation appears to be about -40 to -58 dB relative to the collimated energy.

SECTION IV

CONCLUSIONS AND RECOMMENDATIONS

The work described in this report demonstrates that far-zone results can be obtained on indoor compact antenna ranges. The study was conducted at X-, C-, and S-band frequencies.

Both the point-source range and the line-source range were modified by installing more accurate range reflectors, and better performance was obtained on both ranges. The measured maximum stray radiation levels (relative to the collimated energy) on the improved ranges at X-band are about -44 to -59 dB on the point-source range (PSR-2) and -40 to -58 dB on the line-source range (LSR-2). Higher stray radiation was measured at C- and S-band, but it is attributed to the use of test antennas having broad main lobes. One could expect to measure lower stray radiation at C- and S-band with narrow-beam test antennas, but in this case, a larger range reflector would be required to be compatible with the larger test antennas.

As compact ranges are improved, it becomes more difficult to locate the principal sources of stray radiation. There appears to be an ambient stray radiation level of about -50 to -60 dB relative to the collimated energy in the current laboratory-type environments. To reduce the stray radiation below these levels, it may be necessary to isolate the ranges from their surroundings by using absorbing material. However, note that the required size of the enclosure and the amount of absorbing material would be far less than that required for conventional anechoic chambers.

Stray radiation measurements were made on an elevated 700-foot outdoor antenna range, and the results are shown in Figure 24. Note that even on this outdoor range, the maximum stray radiation levels ranged from about -50 to -60 dB.

A brief study was conducted by Georgia Tech during 1965 to compare antenna pattern measurements which were made on three elevated outdoor ranges; the results are summarized in Appendix B. Note by comparing the limits of the six patterns (outdoor ranges) in Figure 32 with the composite set of patterns (PSR-2 compact range) in Figure 7 that the measurement errors experienced on the compact range are comparable to those experienced on outdoor ranges.

It is recommended that future efforts be devoted to an investigation and experiments to determine the feasibility of the application of compact range techniques to radar reflectivity measurements.

REFERENCES

1. R. C. Johnson and R. J. Poinsett, Compact Antenna Range Techniques, Final Report on Contract No. AF30(602)-3594, RADC-TR-66-15, AD No. 484511L, Rome Air Development Center, Griffiss Air Force Base, New York; April 1966.
2. E. F. Buckley, "Outline of Evaluation Procedures for Microwave Anechoic Chambers," Microwave Journal, August 1963; pp. 69-75.
3. A. L. Holliman, An Improved Point-Source Compact Antenna Range, Interim Report on Contract No. AF30(602)-4269, RADC-TR-67-12, AD No. 811915L, Rome Air Development Center, Griffiss Air Force Base, New York; March 1967.
4. A. W. Love, "The Diagonal Horn Antenna," Microwave Journal, March 1962; pp. 117-122.

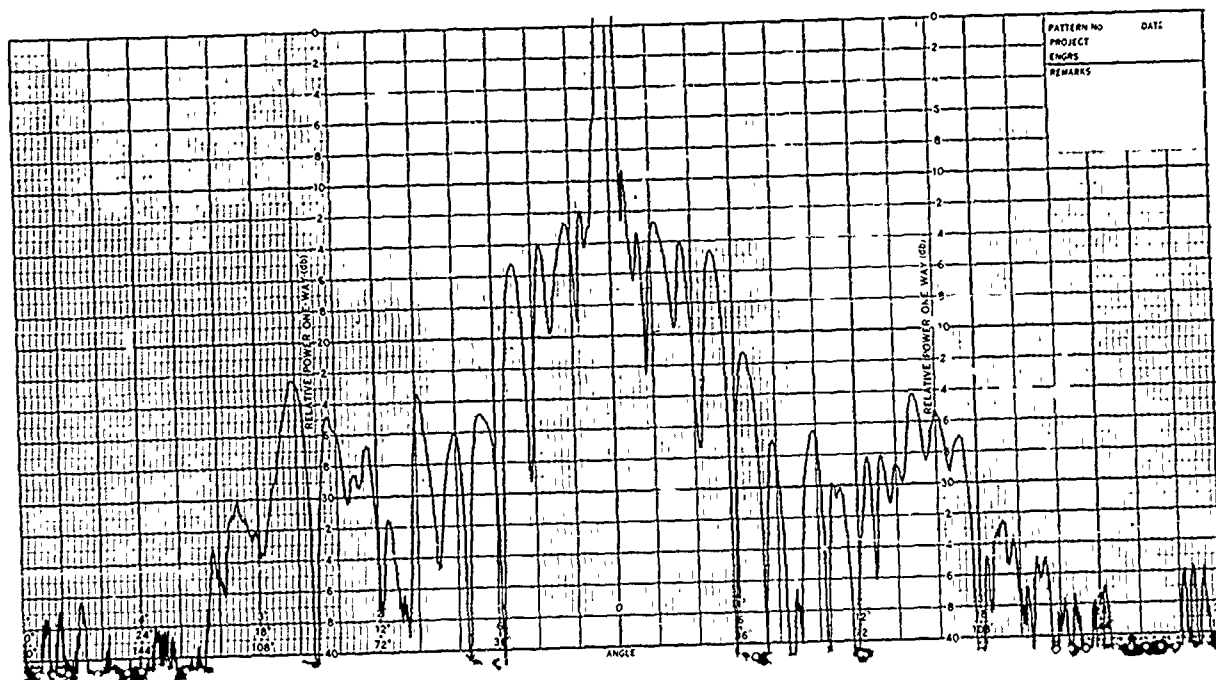
APPENDIX A

ADDITIONAL DATA

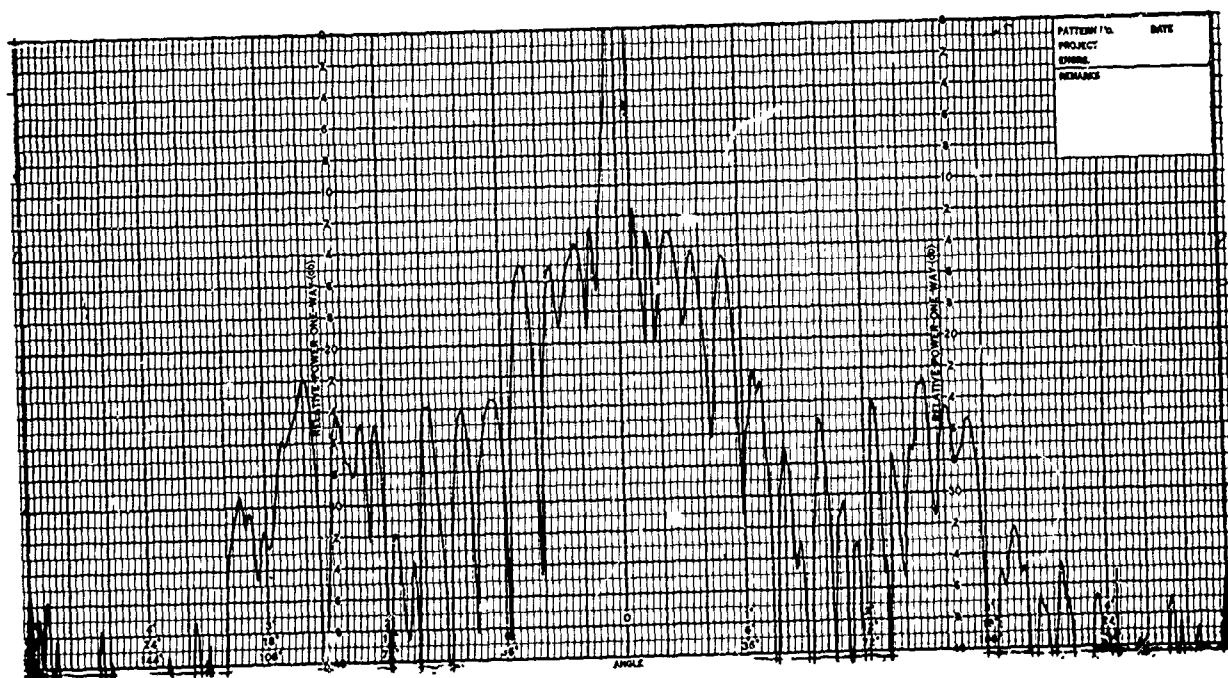
Some additional patterns are presented here for purposes of comparison. Included are 360° azimuth-plane patterns and 60° expanded elevation-plane patterns recorded on both the outdoor and the compact ranges. Each figure contains an outdoor reference pattern and the corresponding compact range pattern. Patterns are included for X-, C-, and S-band frequencies and the level of each pattern with respect to the main lobe level is given in the figure titles.

Figures 21 and 22 are a comparison of the elevation patterns which were recorded on the outdoor range and on the compact ranges at 10 GHz. These patterns were not expected to compare as favorably as the azimuth patterns because the edge illumination at the top of the range reflectors was higher than that at the sides of the reflectors and because the main lobe of the test antenna was directed toward the upper edge of the range reflector when measuring the lower side lobes and toward the range feed when measuring the upper side lobes. However, the comparison is considered to be reasonable.

Additional stray radiation data and a composite set of azimuth patterns recorded on the outdoor range also are included.

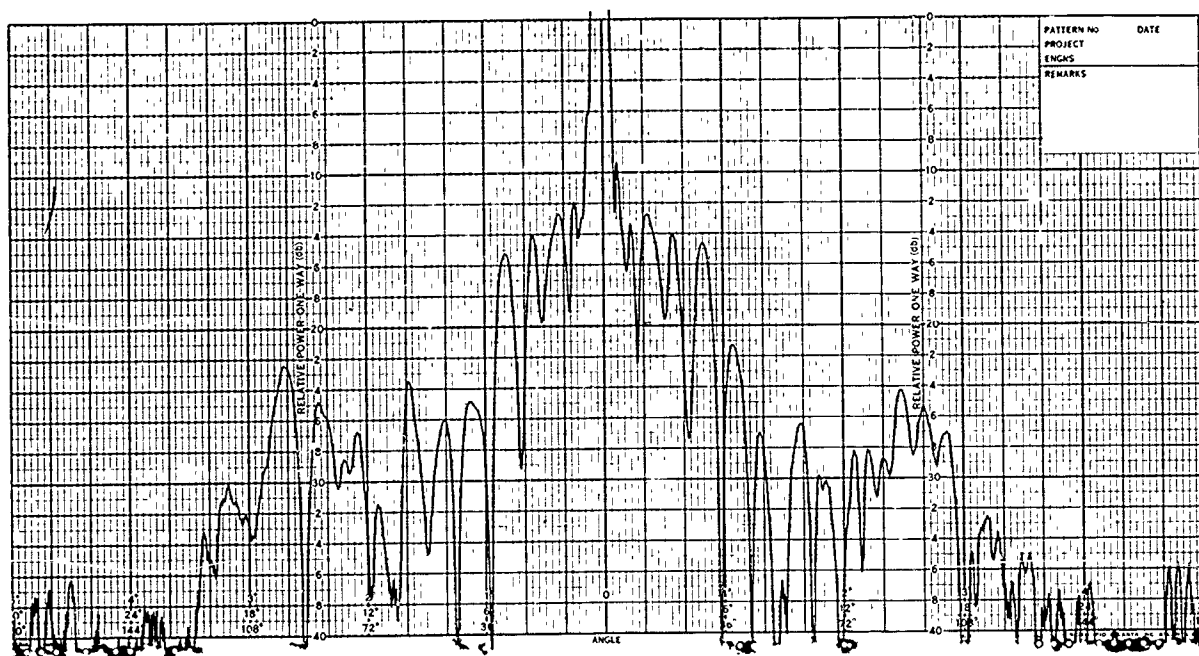


(a) Outdoor range

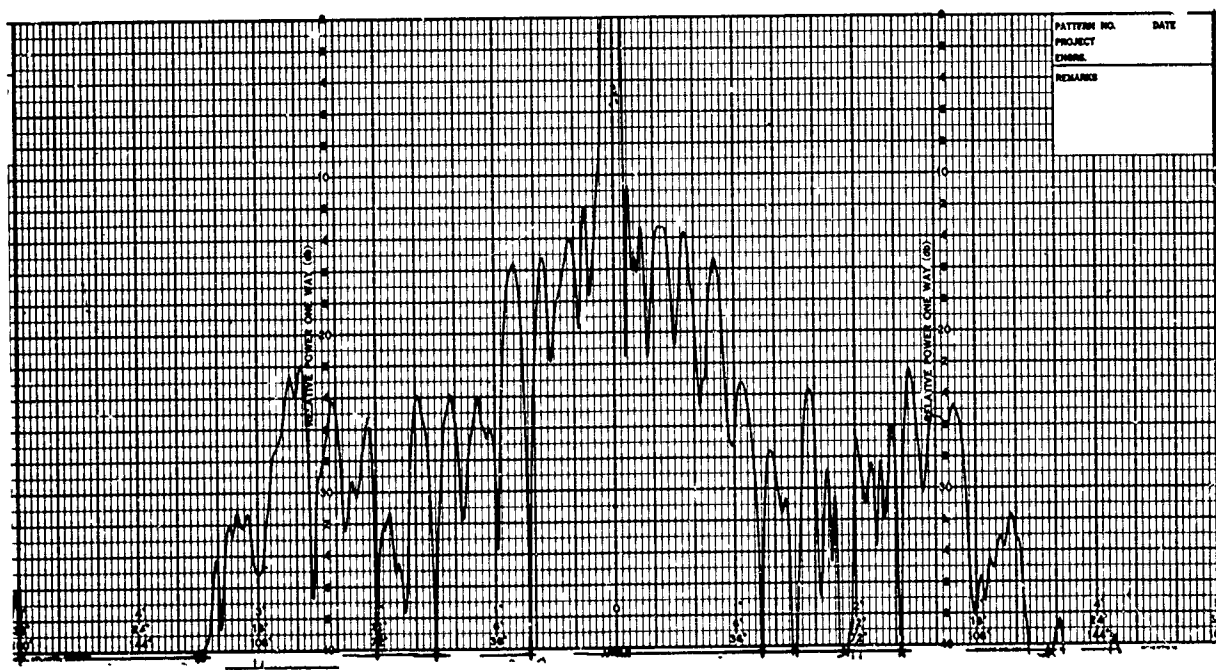


(b) Compact range

Figure 19. Azimuth patterns recorded on the outdoor range and on the modified point-source compact range at 10 GHz. The gain level at the top of the chart is -15 dB relative to the peak of the main lobe.



(a) Outdoor range



(b) Compact range

Figure 20. Azimuth patterns recorded on the outdoor range and on the modified line-source compact range at 10 GHz. The gain level at the top of the chart is -15 dB relative to the peak of the main lobe.

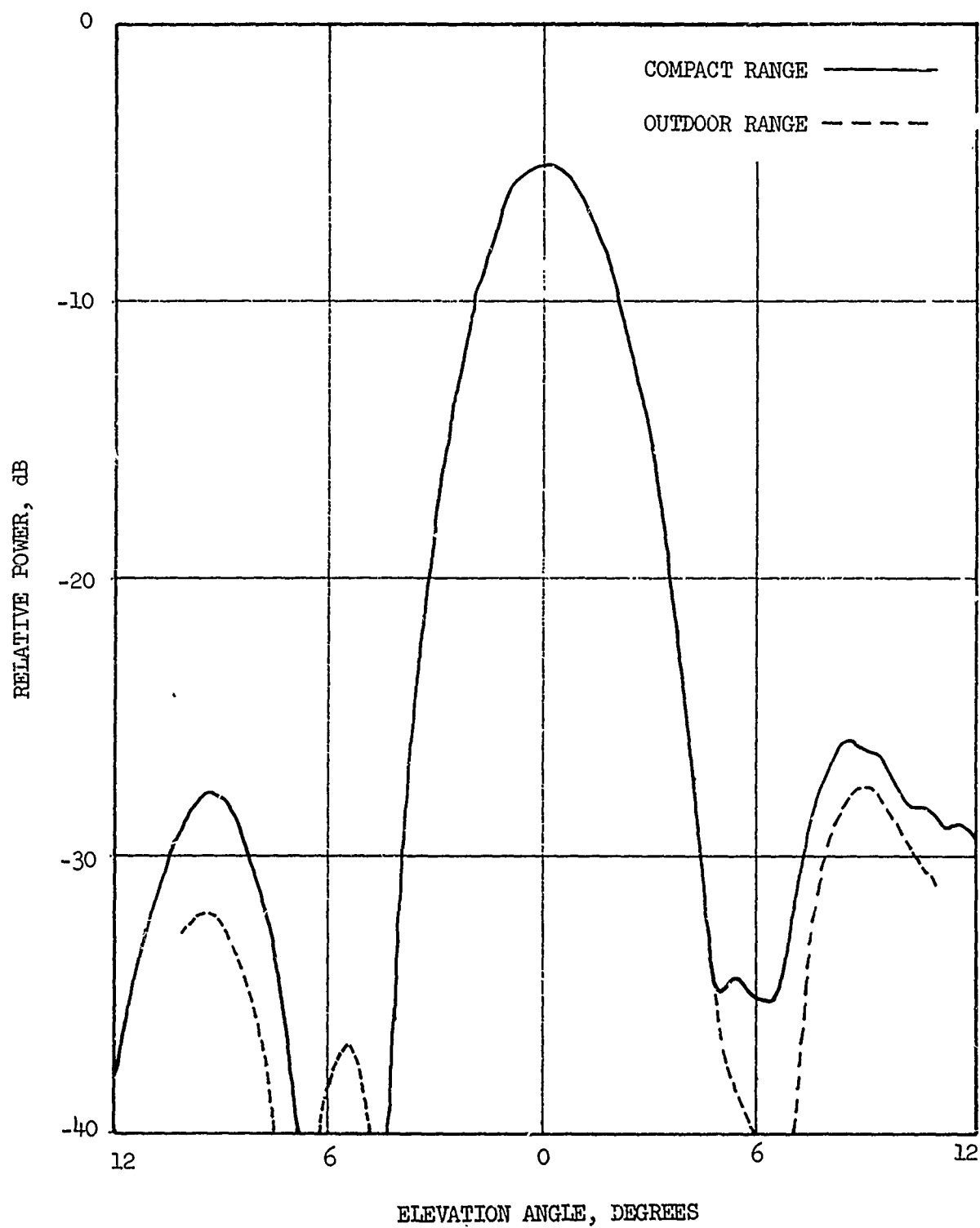


Figure 21. Comparison of the elevation patterns recorded on the outdoor range and on the modified point-source compact range at 10 GHz.

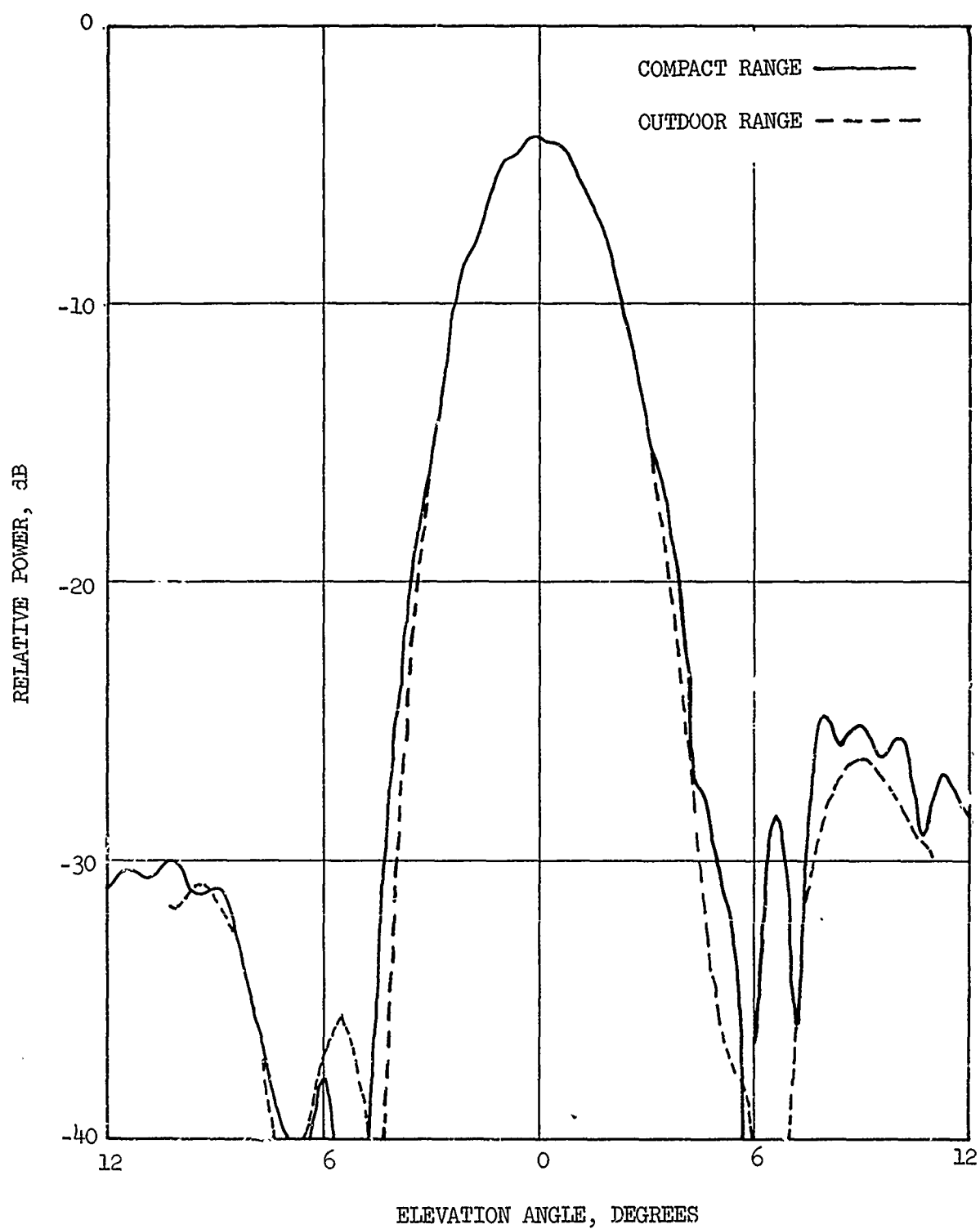
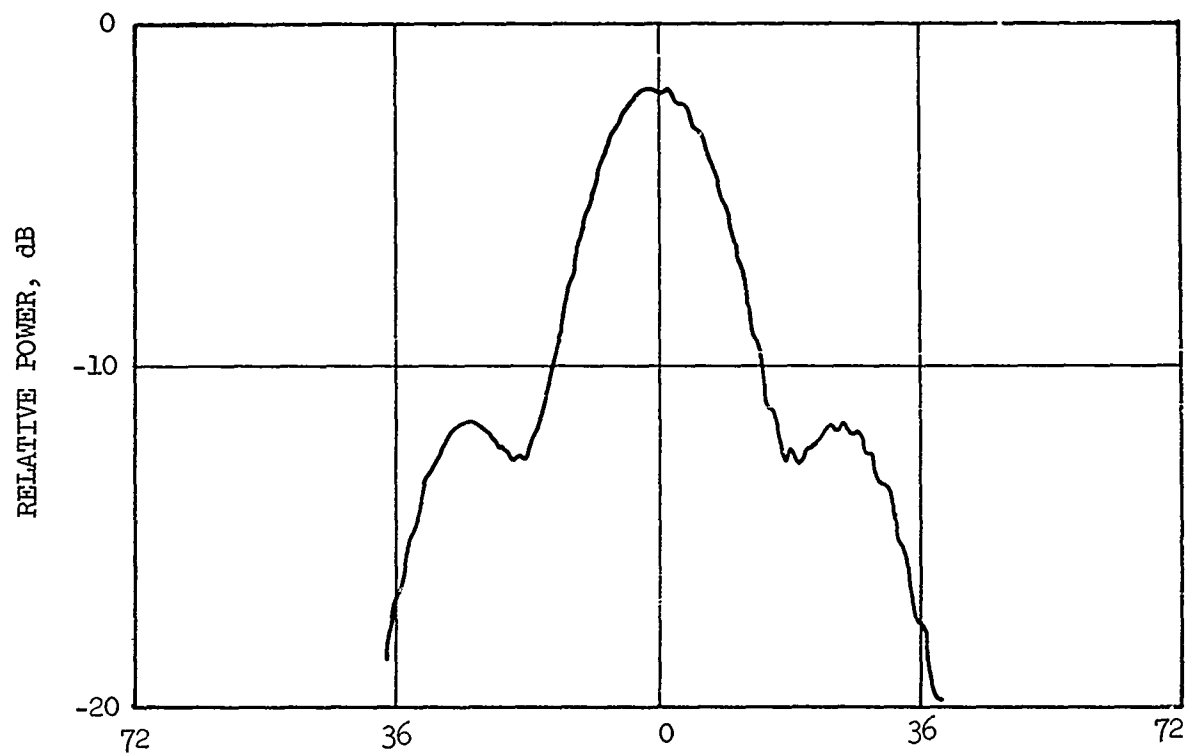
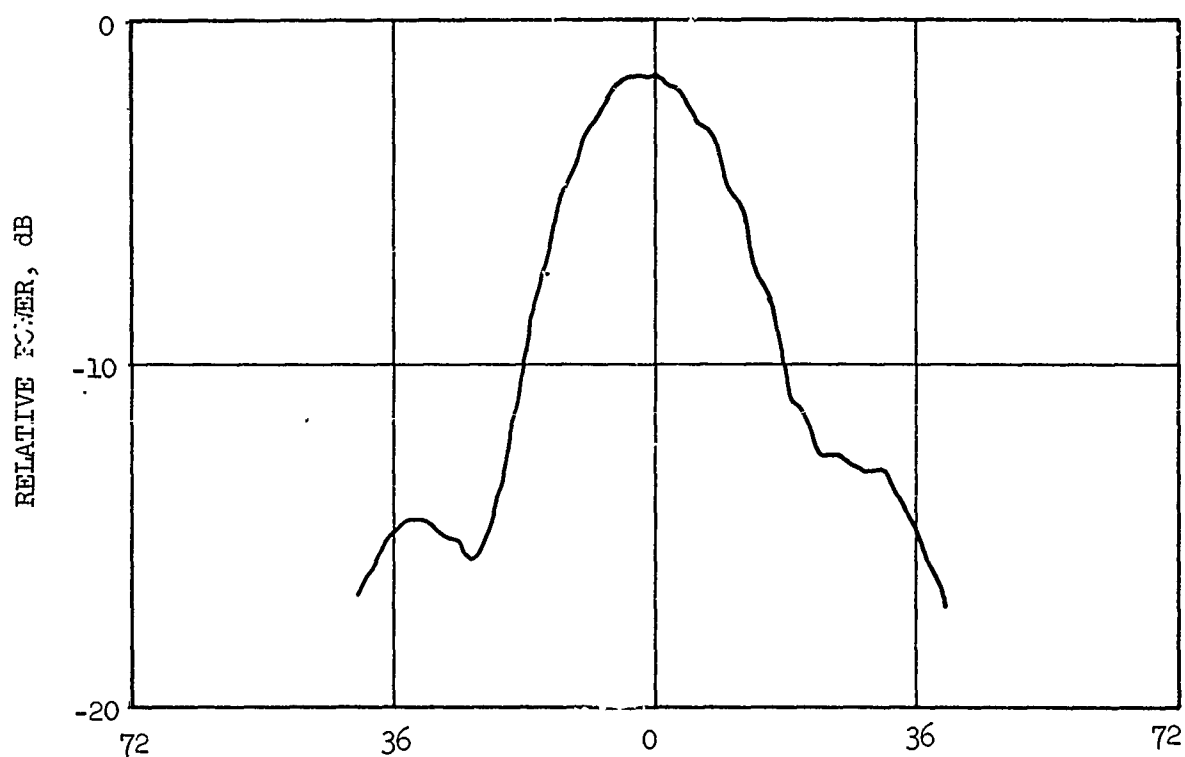


Figure 22. Comparison of the elevation patterns recorded on the outdoor range and on the modified line-source compact range at 10 GHz.



(a) Elevation angle of C-band horn, degrees



(b) Elevation angle of S-band horn, degrees

Figure 23. Elevation patterns of a C-band pyramidal horn test antenna at 5.6 GHz and a S-band pyramidal horn test antenna at 3.0 GHz as measured on the compact range.

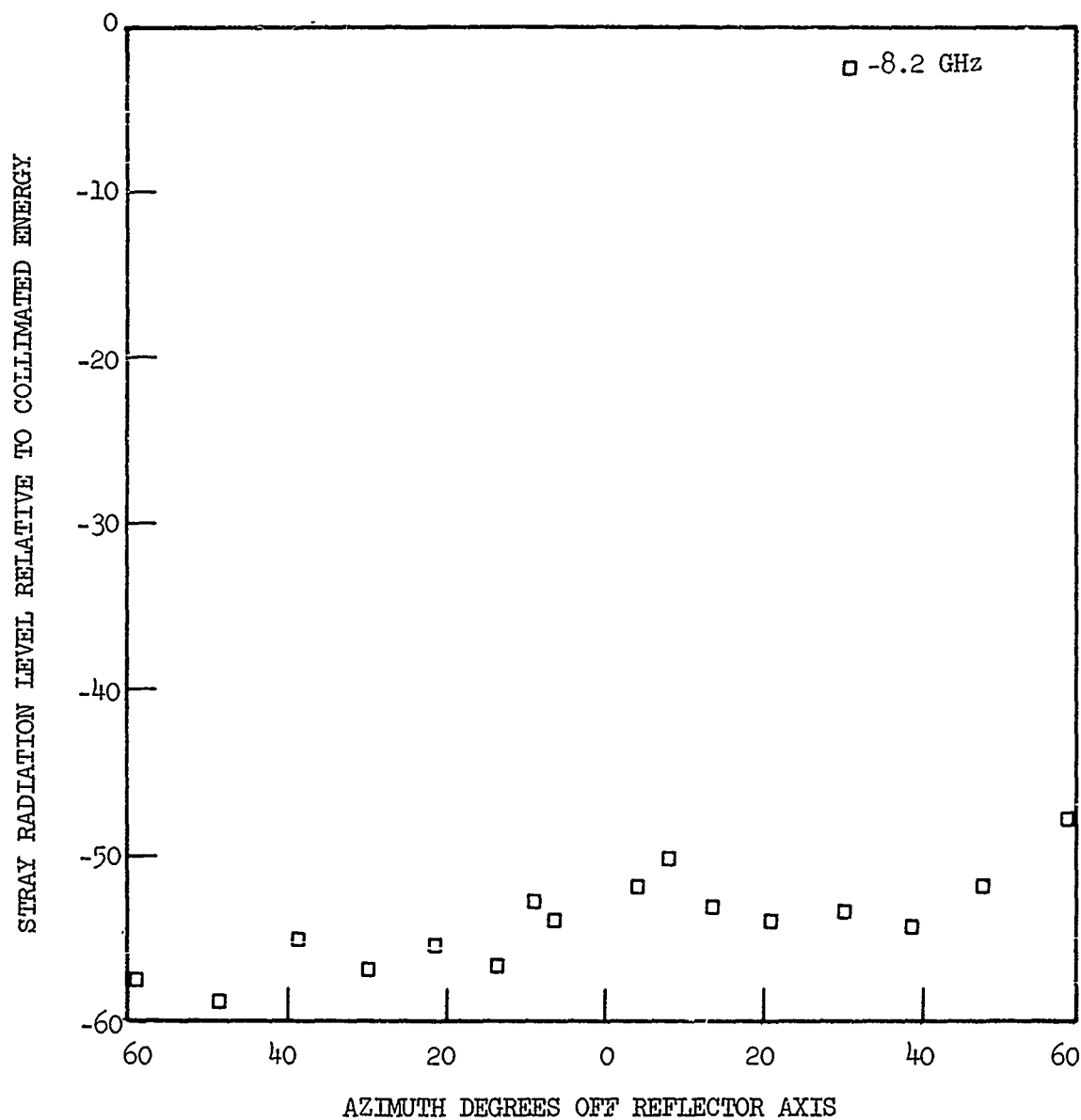


Figure 24. Maximum stray radiation levels as a function of azimuth angle of the test antenna as measured on the outdoor range at X-band frequencies with a 30-inch paraboloidal test antenna.

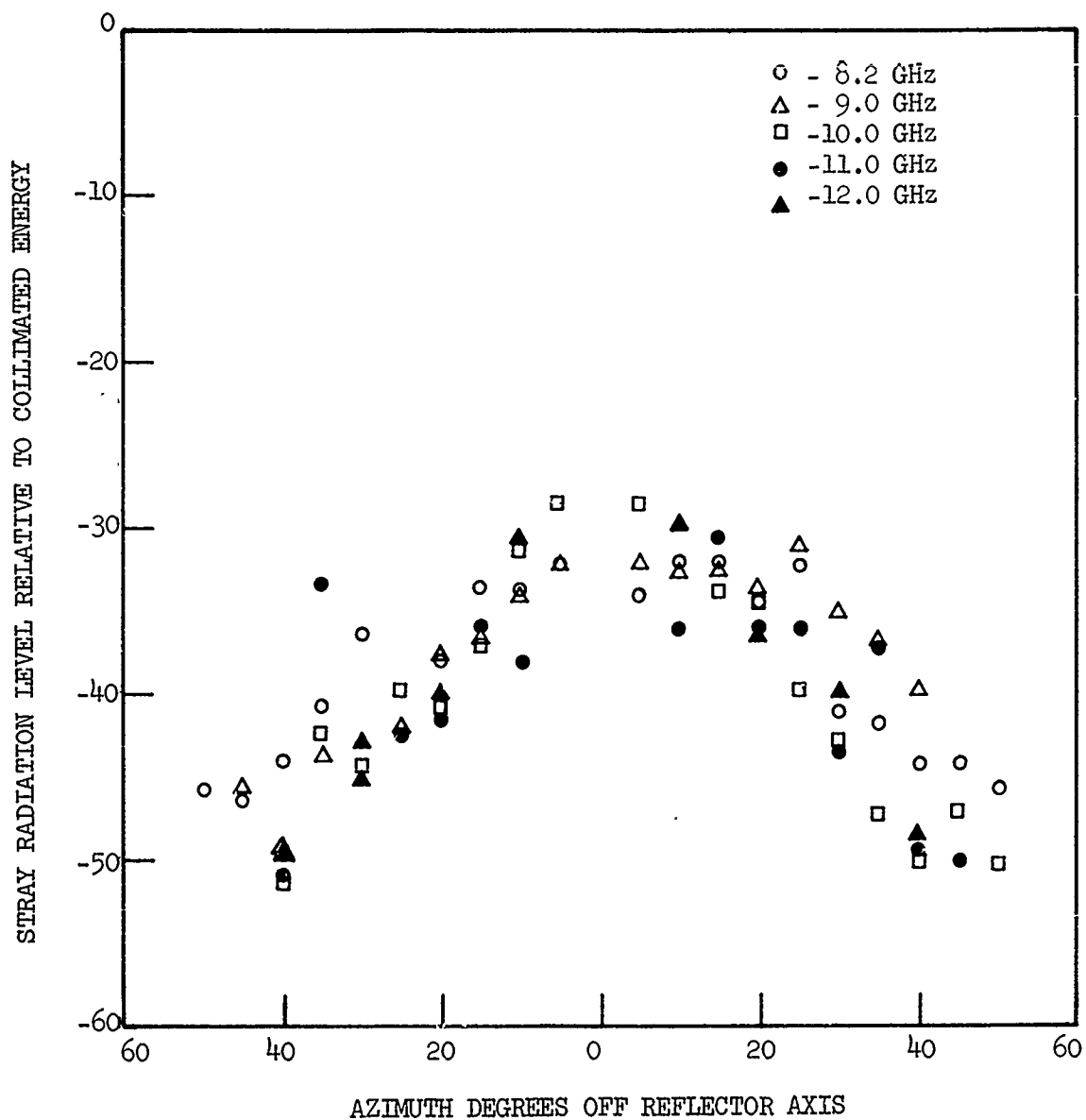


Figure 25. Maximum stray radiation levels as a function of azimuth angle of the test antenna as measured on the modified line-source compact range at X-band frequencies with a 5-5/8 x 7-5/8 -inch pyramidal horn test antenna.

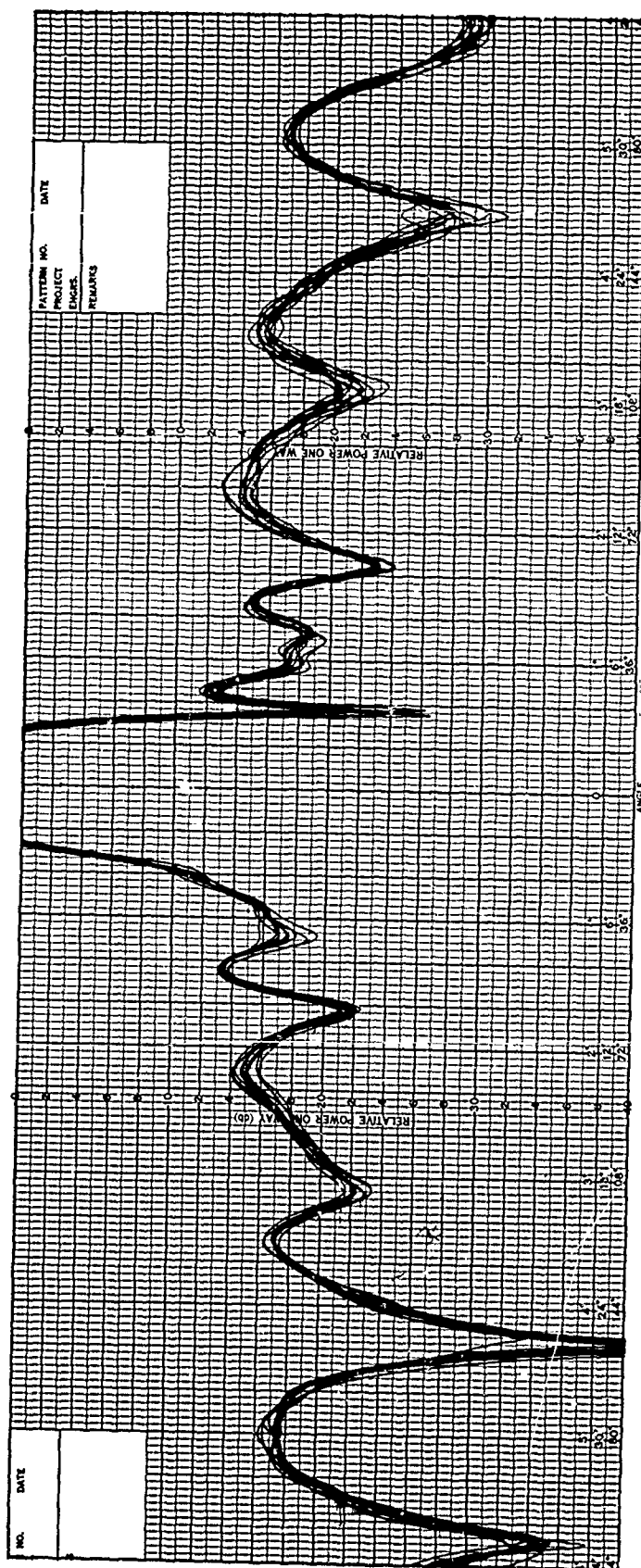


Figure 26. Composite set of azimuth patterns recorded on the modified line-source compact range (LSR-2) at 10 GHz. Each of the ten patterns was recorded with the test antenna located at a different location within the test area. The gain level at the top of the chart is -13 dB relative to the peak of the main lobe.

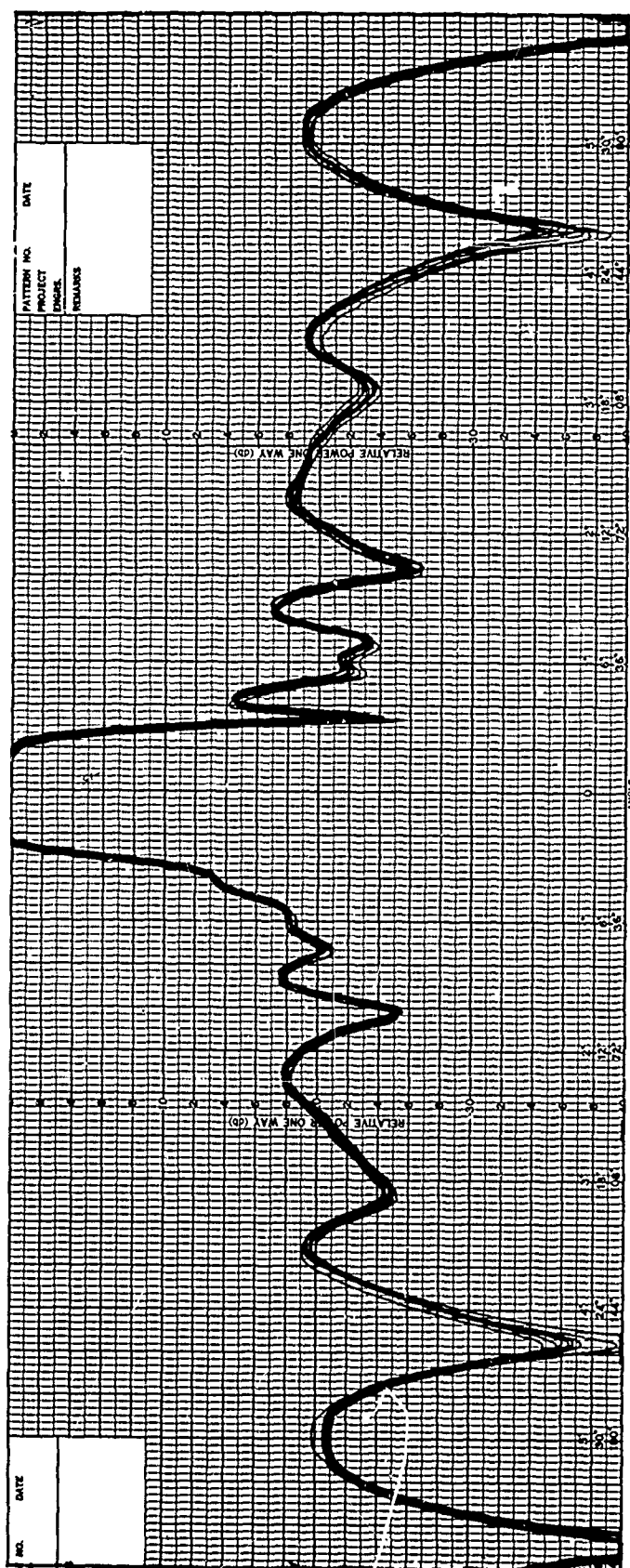


Figure 27. Composite set of azimuth patterns recorded on the outdoor range at 10 GHz. Each of the ten patterns was recorded with the test antenna located at a slightly different location on the range. The gain level at the top of the chart is approximately -10 dB relative to the peak of the main lobe.

APPENDIX B

ANTENNA PATTERNS MEASURED ON THREE MICROWAVE RANGES

Most antenna-range engineers and technicians realize that there are many sources of measurement errors, but seldom do they have the time or the facilities to determine the accuracy of their pattern measurements. A brief study was conducted by Georgia Tech during 1965 to compare antenna patterns which were measured by three separate organizations on their elevated outdoor antenna ranges; the results are instructive.

The test antenna* was a paraboloidal reflector with a horn feed as illustrated in Figure 28, and some of its characteristics were the following:

diameter	30 inches
frequency	10.0 GHz
polarization	vertical
beamwidth	3°
gain	34 dB.

The range crew at each of the three organizations was instructed to record azimuth patterns for two orientations of the test antenna--one with normal orientation (coaxial cable down) and one with the antenna inverted (coaxial cable up). In this manner, six patterns of the test antenna were obtained. No special efforts to reduce range errors were made, and no person participated as a crew member or as an observer during measurements except those employed at the organization.

*The test antenna used for these tests was similar but not identical to the test antenna used to evaluate the compact ranges.

Since the minor-lobe structure was of great interest and since the recording equipment was limited to a 40 dB dynamic range, a pair of patterns (each at a different power level) was recorded for each orientation. The recorded patterns from each organization were then traced by a draftsman at Georgia Tech to obtain six composite patterns showing a 60 dB range.

The six composite patterns are shown in Figures 29, 30, and 31. Note that the minor lobes measured on Range C appear to be about 2.5 dB lower than those measured on Ranges A and B; this difference is believed to be the result of an error in the pattern calibration on Range C.

The Range C patterns were corrected by raising the minor-lobe structure 2.5 dB, and then the six patterns were compared. The dashed lines in Figure 32 indicate the limits of the measured patterns; in other words, all six patterns which were measured on the three antenna ranges lie within the dashed lines.

Figures 29, 30, and 31 indicate that the patterns for normal and inverted orientations are quite similar on each of the three ranges, and Figure 32 indicates that the three ranges agree reasonably well. The measured side lobes agreed within about 1 to 2 dB.

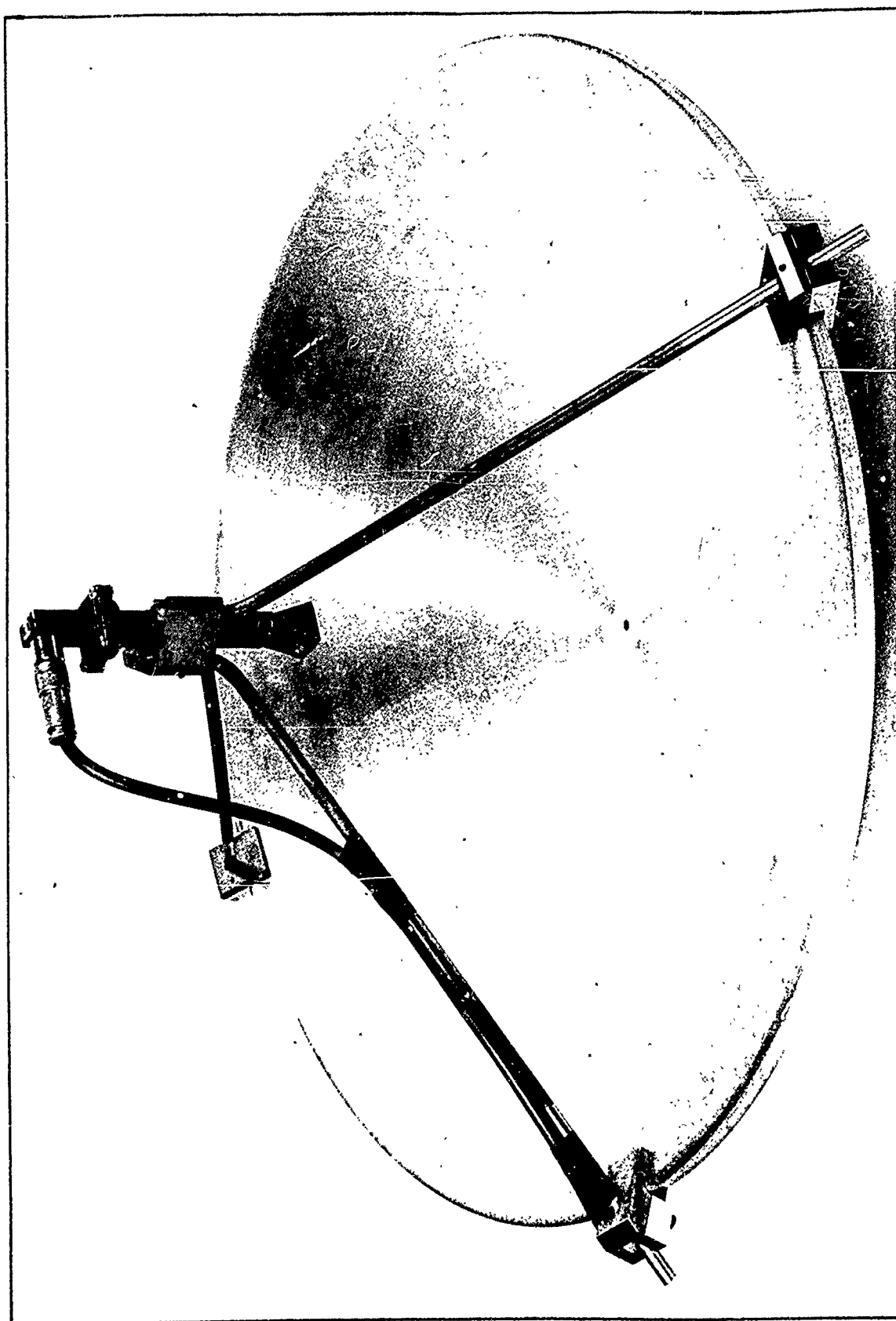


Figure 28. Photograph of the 30-inch parabolic test antenna.

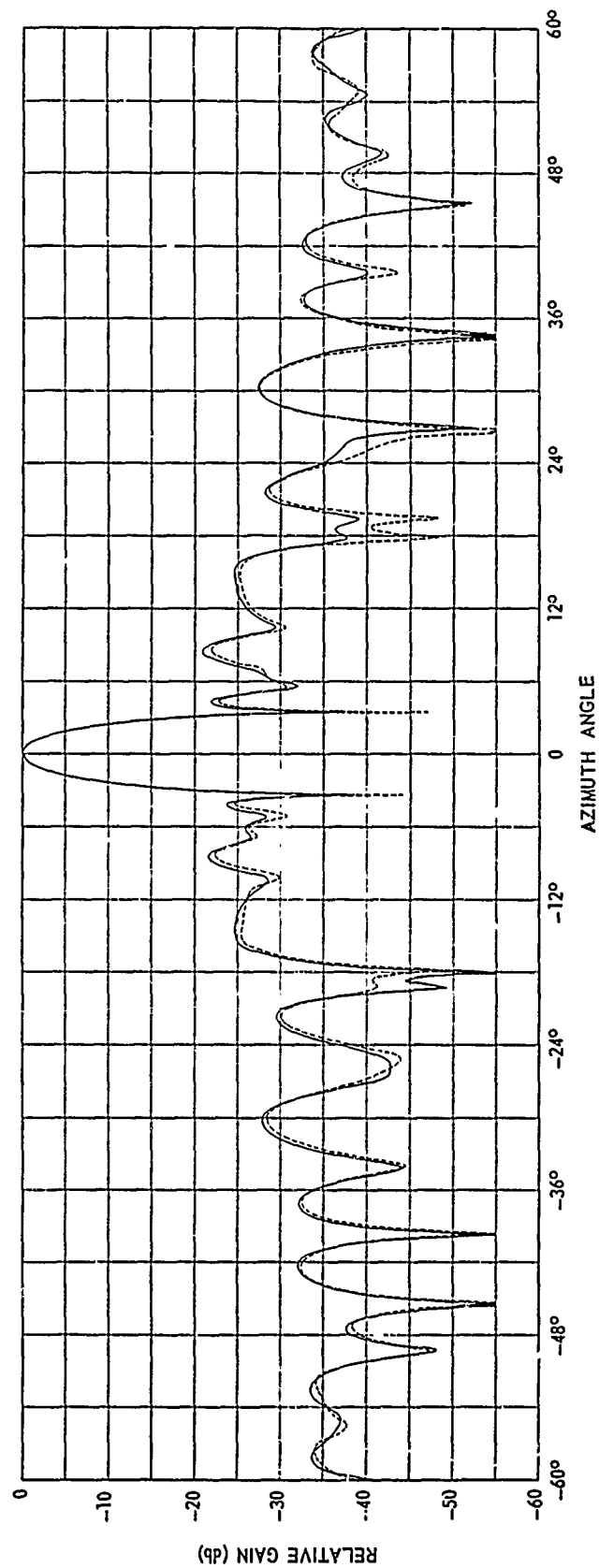


Figure 29. Azimuth patterns for both normal and inverted orientations of the test antenna recorded on Range A.

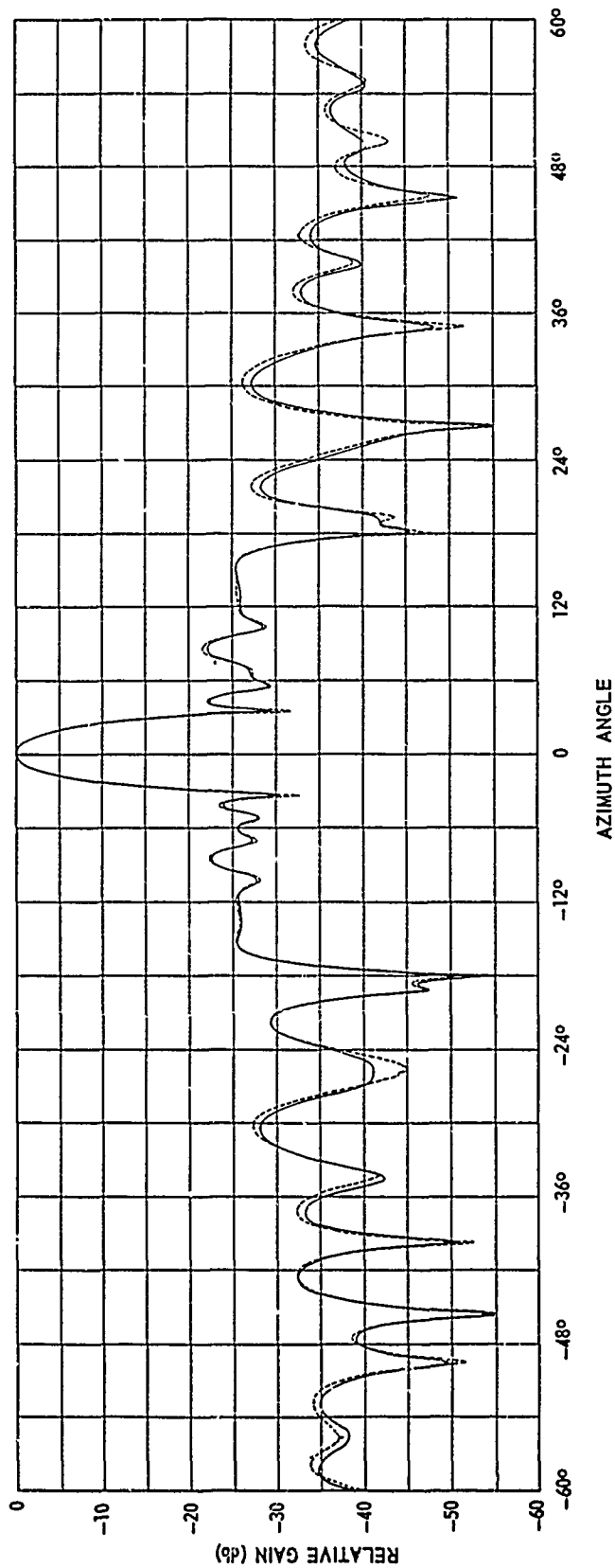


Figure 30. Azimuth patterns for both normal and inverted orientations of the test antenna recorded on Range B.

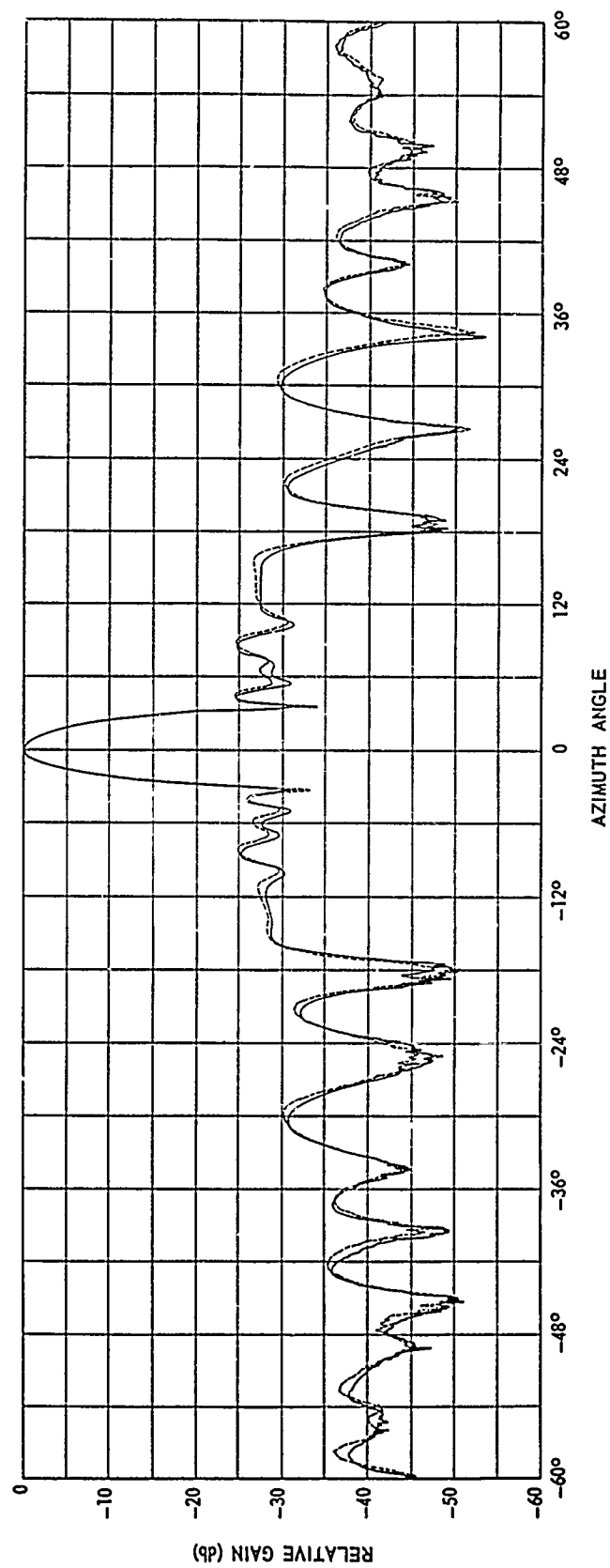


Figure 31. Azimuth patterns for both normal and inverted orientations of the test antenna recorded on Range C.

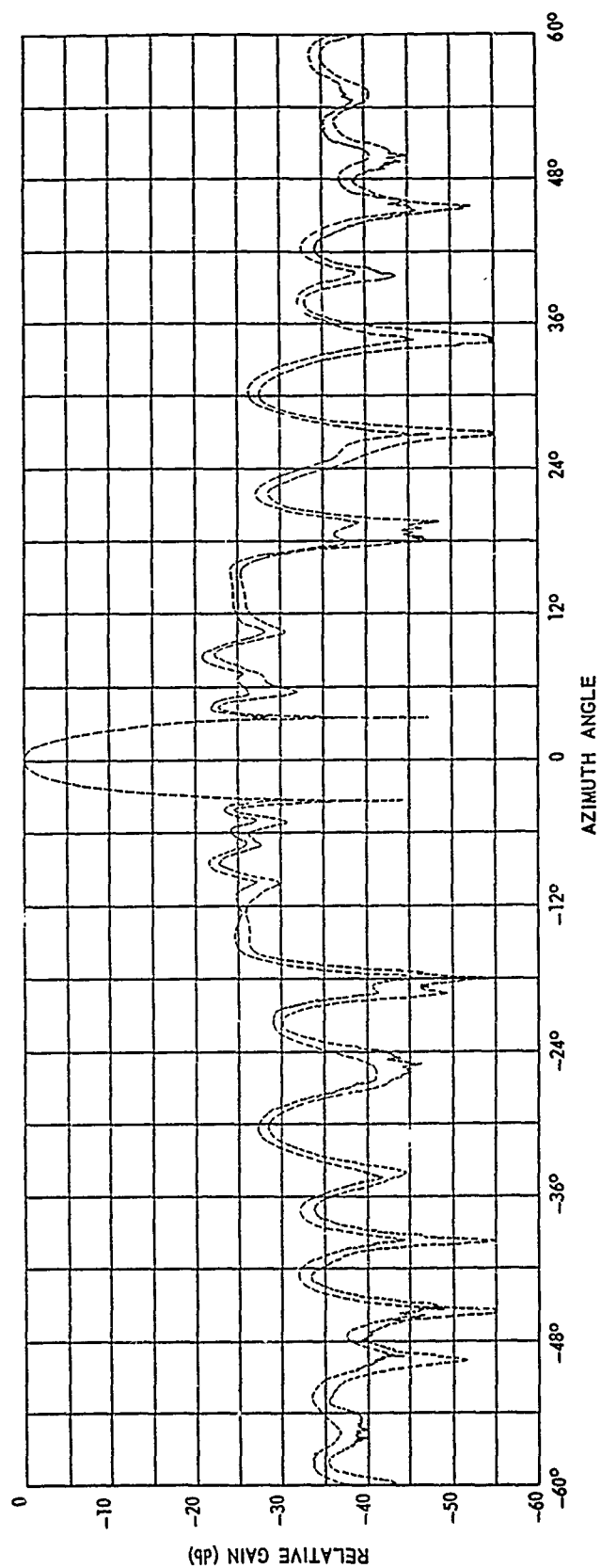


Figure 32. Limits of the six patterns with the minor lobe structure which was measured on Range C arbitrarily raised 2.5 db.

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13. ABSTRACT A point-source and a line-source "compact antenna range" were modified by installing on each a range reflector having a more accurate surface contour and by shielding the point-source reflector edge and its feed with absorbing material. Stray radiation measurements and antenna pattern measurements were made on both ranges at X-band (8.2 to 12.0 GHz) frequencies using a 30-inch paraboloidal test antenna; these measurements also were made on the point-source range at C-band (5.4 to 5.8 GHz) and at S-band (2.8 to 3.2 GHz) frequencies using pyramidal horn antennas. Results at X-band frequencies are compared with those obtained on previously constructed similar compact ranges, and they demonstrate that the range performance was improved. Antenna radiation patterns compare very favorably with those measured on outdoor antenna ranges. This document is subject to special export controls and each transmittal to foreign governments, foreign nationals or representatives thereto may be made only with prior approval of RADC (EMLI), GAFB, N.Y. 13440.		

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	ROLE	WT	ROLE	WT	ROLE	WT
Ranges (Establishments) Test Facilities (Antenna Test Range Techs)						

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